Issued March 16, 1911.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—BULLETIN No. 75.

MILTON WHITNEY, Chief.

LAWN SOILS.

BY

OSWALD SCHREINER,

Scientist in Charge of Fertility Investigations,

AND

J. J. SKINNER,

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WASHINGTON:

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LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Bureau of Soils,
Washington, D. C., November 16, 1910.

Sir: I have the honor to transmit herewith the manuscript of a paper entitled "Lawn Soils," by Dr. Oswald Schreiner and Mr. J. J. Skinner, of this bureau. The article embodies an exposition of the soil factors involved in lawn building and maintenance.

The material is especially valuable in guiding park authorities in the selection of soil materials for the improving and making of lawns, parks, embankments, and terraces, a subject on which the advice of this bureau is continually being sought, and I have therefore the honor to recommend that the article be published as Bulletin No. 75 of the Bureau of Soils.

Respectfully,

Milton Whitney,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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LAWN SOILS.

INTRODUCTION.

Lawns are the groundwork of the pictures, as it were, formed by flowers, shrubs, trees, and buildings, public and private, in city streets, city parks, public grounds, country estates, and similar places. The widespread movement of civic art to improve and beautify cities and towns by park and art commissions, civic associations, and individuals naturally creates a demand for information concerning lawns, their improvement, soil requirements, fertilization, maintenance, soil suited for filling-in or top dressing, and similar questions. It is to supply this general demand for soil information regarding lawns that the present bulletin is designed.

The selection of grasses and their description as to appearance and manner of growth, color, and other details; the seeding, weeding, mowing, and rolling the lawn, and the implements required in making and taking care of it, as well as its general handling by the gardener after or during its establishment; the location of drives and flower beds; the planting of shrubbery, both as to kinds and arrangement; in short, the establishment of a rural or park picture of which the lawn forms the groundwork, has been admirably presented in a number of articles, bulletins, and books, to which the reader is referred for specific information on these and allied details,[a] the present bulletin dealing mainly with the distinctly soil problems, the selection of the proper soil and its manipulation.

In this bulletin is presented the character of soils in respect to the minerals and organic materials composing them, as well as the kind and amounts of different-sized soil particles which determine the suitability of soils for lawn making. The texture of soils as related to lawns is especially emphasized and the relation of surface soil to subsoil receives consideration in regard to its effect on lawns. The

[a] In this connection see The Lawn, by L. C. Corbett, Farmers' Bulletin 248, U. S. Dept. Agr. (1906); Lawns and Lawn Making, by F. Lamson-Scribner, Yearbook, p. 355, U. S. Dept. Agr. (1897); Lawns and How to Make Them, by L. Barron, New York (1906); Canada Bluegrass, by R. A. Oakley, Farmers' Bulletin 402, U. S. Dept. Agr. (1910).

difference between land devoted to lawn culture and land growing a farm crop is pointed out and the movement of soil moisture and its dependence on texture, as well as its importance to the maintenance of a good greensward is explained.

The presence of harmful compounds in certain soils is shown and their bearing on lawn construction and preservation is considered, as is also the influence of trees on lawns and the remedial measures to be employed.

The soils suited for the building of lawns, parks, parked embankments, and terraces, etc., receive special consideration, and the best methods for building up artificial grounds by the hauling in of such suitable soil material, both for subsoil fillings and for surface layering, are given full consideration, a list of soil types well adapted to grass growing being given for this purpose.

While the material here presented is largely for the purpose of aiding in the establishment and improvement of relatively large tracts of land for public use, the individual owner of a small tract of land in town or city has also been kept in mind, as it is largely upon the beauty of the numberless small lawns that the general appearance of cities depends, rather than upon extensive parks, either natural or artificial.

THE SOIL HAS VITAL FUNCTIONS.

The soil can not be considered as the dead, inert remains of rocks and previous vegetation, but must be considered as an accumulation of such material in which the processes of formation, alteration, and transposition are still at work. In other words, the soil in its entirety is not dead or inert, but endowed with functions analogous to those of life itself. In it take place the same processes of solution and deposition that have taken place in past ages, and are taking place to-day in the geologic processes connected with the action of water on the rocks and minerals of the earth's crust. In it take place the same physical and chemical interactions as take place in the movement of subsurface waters generally, resulting in ore formations or depositions. In it take place the same processes of fermentation, digestion, or decay of organic materials as take place in animals and plants or in the production of industrial products, such as cheeses, wines, and beers, brought about in the soil as in these other processes by means of ferments, enzymes, bacteria, and fungi or molds. In it take place the same processes of oxidation and reduction which play so enormous a part in all life processes, and recent researches have shown the nature of compounds in the soil organic matter to be the same as those derived from such life processes or from similar laboratory processes of digestion, oxidation or reduction.

NATURE OF THE MINERAL AND ORGANIC MATERIALS OF THE SOIL.

Lawn soil, like other soils, consists of soil solids, of soil fluid, and of soil gases.[a] The relative proportions of these three determines the moisture content and the porosity, and these are greatly influenced by the relative sizes of the soil particles which make up the solid part of the soil. This solid part is composed of both inorganic and organic material. The inorganic material, which forms by far the larger part of the solid soil particles, consists largely of small rock fragments and individual minerals. Recent soil studies have shown that soils contain representatives of all the common rock-forming minerals, in well-defined crystalline form, together with the products of change produced through chemical interaction with the soil fluid. These mineral particles are largely derived from rock disintegration or decay *in situ* or else transported and commingled with material from other places through the agencies of wind, water, and ice. The organic material consists of matter, both living and dead. The living forms, excluding for the present larger living forms such as earth worms, larvæ, beetles, and burrowing animals generally, consist chiefly of animalcules, fungi or molds, bacteria, and roots, rootlets, and root hairs of growing plants. The organic matter not living consists of the yet organized débris with recognizable structure of former life and the structureless and unorganized products of changes produced in the latter through oxidation, reduction, and chemical changes generally, whether induced by the living forms present or by lifeless processes.

The soil fluid in the lawn consists of water and dissolved minerals, gases, and organic substances. This soil fluid is the important medium through which the growing grass obtains its necessary water and nutrient materials for building up plant tissues, except carbon dioxide, which it obtains largely from the free atmosphere above the soil. The importance of the soil fluid will be discussed more fully later.

The soil gases are similar to the free atmosphere above the earth, and contain chiefly oxygen, nitrogen, and carbon dioxide, although the proportion of these differs greatly from that in the free atmosphere, the oxygen being usually relatively lower and the carbon dioxide relatively much greater, owing to the removal of oxygen in the processes of oxidation within the soil and the evolution of carbon dioxide as the result of such processes. These oxidation processes are usually beneficial and requisite for best plant growth and it is, therefore, necessary, if they are to be continuous in a soil, that good aera-

[a] See in this connection, The Mineral Constituents of the Soil Solution, by Frank K. Cameron and James M. Bell, Bul. 30, Bureau of Soils, U. S. Dept. Agr. (1905).

tion be promoted by good structure, giving greater air space and freer air movement, by drainage, which allows air to penetrate deeper into the soil, and by cultivation and tillage, which stir the soil.

THE MINERAL PARTICLES AND ORGANIC MATTER AS CARRIERS OF ELEMENTS NECESSARY TO GRASS GROWTH.

The mineral particles make up approximately 97 per cent of the solid matter of the soil and a still larger percentage of the subsoil. These minerals are the carriers of the elements necessary for plant growth: Potassium, sodium, calcium, magnesium, iron, manganese, chlorine, sulphur, phosphorus, and others of less importance. The grasses and other plants obtain these elements from the minerals through the intermediary agency of the soil fluid, which is capable of dissolving these minerals, in whole or in part, slowly but continuously, and which is thus able to transfer these necessary chemical elements from the solid minerals to the plant roots, where they are absorbed to play their respective parts in the life of the plant. The movement of soil fluid from great depths also brings in material which it has dissolved from the subsoil. Different minerals are carriers of these chemical elements, no one mineral carrying all, but the different mineral species in any agricultural soil are, as already mentioned, sufficiently numerous to represent carriers of all these necessary elements, although perhaps not always in the forms to produce maximum efficiency in producing plant growth. The nitrogen necessary for plants, though not derived from minerals, may nevertheless occur in mineral or inorganic forms such as nitrates of sodium, potassium, calcium, or as ammonium salts, and it is in these forms that it is chiefly absorbed by plants. Most of the nitrogen in the soil, however, is contained in organic forms resulting from previous vegetable or bacterial life. While some of these nitrogenous organic compounds may be directly used by grasses, the larger proportion are undoubtedly changed by molds, bacteria, and other agencies into the above-mentioned forms of ammonium salts and nitrates. In addition to the nitrogenous remains of former life, there is in many, if not in most soils, a process of nitrogen fixation from the gaseous state in which it is present in the air, thus causing a further source of nitrogenous compounds in the soil, directly or indirectly usable by plants. The chief agents in this nitrogen accumulation are bacteria and fungi in the soil in association with certain plants. Thus, for instance, the legumes, among them alfalfa, clovers, and cowpeas, have on the roots nodules containing such nitrogen gatherers.

Like the nitrogen, the phosphorus and sulphur are regained from organic matter by decay in the soil, as are also the inorganic constituents of vegetable matter, the salts of potassium, sodium, calcium, and other elements.

IMPORTANCE AND VARIABILITY OF THE ORGANIC MATTER IN THE SOIL.

The organic matter forms a much smaller percentage of the solid matter of the soil, usually less than 3 per cent in the soil, and much less in the subsoil, though the quantity varies greatly in different soils. Smaller in amount than the mineral material, it is nevertheless of the greatest importance in the fertility of the lawn. As a carrier and source of nitrogen its importance has already been emphasized. It contains also the other elements necessary to plant growth, derived largely from the decomposed plant débris. In addition to this function of organic matter, the material is itself the food and sustenance for the bacteria of the soil and the fungi contained therein, the useful functions of which in inducing changes helpful to plant growth have already been mentioned. Under unsuitable conditions, however, the changes occurring in this organic matter may proceed in an entirely different manner, much as grape juice may under certain conditions yield an excellent wine and under other conditions a foul liquor of unpalatable and acid properties.

The mineral material of the soil under the action of water gives a very similar solution under a great variety of climatic conditions, but this is not the case with the changes produced in the organic débris which has accumulated in the soil. The plant débris and other organic matter will have undergone a different change, the course depending upon whether these changes took place largely under water, as in bogs and swamps; whether they took place in higher or upland soils; whether under the influence of arid conditions and high temperature, or humid conditions and high temperature, or humid conditions and low temperature; whether the soil is calcareous or not; whether drainage is good or poor, or other varying conditions. While the mineral material in all these soils is similar, the organic residues of change are widely different and become therefore an important though not well-recognized factor in the differences noticed in such soils, both as to kind of natural vegetation and suitability to and yield of cultivated crops. Recent researches have brought out strongly this difference in the organic residues in soils, and the isolation of some of the constituent parts has shown the presence in unproductive soils, including some lawn soils, of material distinctly harmful to plants, interfering with their normal growth and ability to absorb the nutrient elements present in the soil solution.[a]

In addition to the direct influence of the organic matter of the soil upon the crop growing therein, either favorable or unfavorable,

[a] The Isolation of Harmful Organic Substances from Soils, by Oswald Schreiner and Edmund C. Shorey, Bul. 53, Bureau of Soils, U. S. Dept. Agr. (1909).

there are other effects of the organic matter. Important among these is its influence on the other great controlling soil factors; the solubility of the soil minerals, the physical structure of the soil granules, the water-holding power of the soils are all influenced by the presence of different kinds of organic matter. As illustration may be cited the case of a soil which would not become properly wetted, either by rain, irrigation, or movement of water from the subsoil, with the result that the land could not be used for profitable agriculture. An investigation showed this property to be due to the organic matter in the soil, which was of such a nature that, when extracted, it had all the properties of a varnish, repelling water to an extreme degree. The soil, once freed of this organic ingredient, had a high water-holding power. From still other soils bodies of an extremely waxy nature have been isolated, and it can thus be seen that certain kinds of organic matter are important as the cause of the low water-holding power of some soils, although in general, under favorable conditions, the presence of the organic remains of plants increases the power of soils to hold moisture—an important factor in lawns. The isolated organic matter from such soils shows a high ability to hold water, either physically or in loose chemical combination.

SOILS AS RELATED TO LAWNS.

The soil particles vary largely in size. It is this difference in the size of soil particles and the proportions in which they are present in soils that has given rise to the different classes of agricultural soils, such as the clays, clay loams, sands, and sandy loams. This difference determines the texture of the soil. The texture is a particularly important factor in a successful lawn, as it has a very marked influence upon the kind of grass, or combination of grasses and clovers, best suited to the soil; the ability for simultaneous tree, shrub, and grass growth; the ability to hold sufficient moisture to carry the grass through a prolonged drought; the establishing of good natural drainage, sufficient aeration, and similar requirements. The texture of a soil is not readily recognized without considerable experience, and even then it is best to make a mechanical analysis; that is, an actual separation into the various-sized particles which make up the soil mass. For this purpose the soil sample is agitated with water, preferably containing some ammonia, to aid in the complete disintegration of soil lumps or aggregations of particles. By pouring off the liquid, repeating the operation several times, the silt and clay remaining in suspension are separated from the coarser particles of sand and minerals. These coarser particles are then separated, after drying, into five distinct classes, according to size, by sifting them through a series of sieves having different-sized meshes, the coarser mesh being 1 millimeter and the finest consisting of silk bolting cloth. The fine particles suspended in the water can be further separated into silt and clay by means of a special apparatus, a centrifuge, which, running at a certain speed, causes the settling of the silt, the clay remaining in suspension. In practice this separation is controlled by means of a microscopic examination. In this way a sample of soil is separated into seven different-sized particles: Clay, silt, very fine sand, fine sand, medium sand, coarse sand, and fine gravel. The photomicrographs of these various soil separates shown in Plate I, and the relative sizes of these in terms of the number required to cover a linear inch given in the following table, will give an idea of the comparative sizes and appearance of the different-sized particles comprising the soil. The extreme fineness of the clay does not permit of a photomicrograph being made with the same magnification.

Size of soil particles of different grades.

Soil particles.	Number of particles required to form a linear inch.
Clay	5,000 and over.
Silt	500 to 5,000.
Very fine sand	250 to 500.
Fine sand	100 to 250.
Medium sand	50 to 100.
Coarse sand	25 to 50.
Fine gravel	12 to 25.

The various percentage relationships of these different grades determine the texture of the soil and the class to which it belongs; that is, they determine whether it is a sand, a loam, a clay, or an intermediate soil class. The following definitions based on the texture as found by examination of many thousand field soils will be useful as a guide in selecting soils suitable for lawn or park purposes, and for the production of lawn soils by proper mixing of two or more soils of different texture.

These soil classes fall naturally into two divisions, the heavier and the lighter soils. The heavier soil classes, described below, contain comparatively large amounts of the two finer grades of soil material—silt and clay. The lighter soils contain a large percentage of definite soil grains, especially the finer sands. In other words, in the heavier soils are found large amounts of silt and clay particles, with vanishingly small amounts of the more definite soil grains; in the lighter soils are found large amounts of the definite grains, with vanishingly small amounts of silt and clay on the one hand and the coarser grades on the other. The latter grades become dominant only in very coarse and sandy soils. The texture of a clay soil, a loam soil, a sandy loam soil, and a sandy soil are shown in Plate II to illustrate this point.

The structure of soils is an important factor aside from the influence of texture. Soil structure, or the arrangement of the constituent particles with reference to each other, as determined by lime content, organic matter content, and other factors, has much to do with the success or failure of lawn grasses. Most grasses of the desirable kind find in stiff plastic clays, such as the Susquehanna clay, a decidedly unfavorable environment. The only possible way to induce anything resembling a thrifty growth of grass on such soil is to bring about a more friable structure through the flocculating influence of lime and the loosening effect of incorporated organic matter and frequent soil stirring.

On the other hand, comparatively light soils, as loams and fine sandy loams, frequently show a marked tendency to bake and compact in a way to cause such excessive surface loss of moisture in dry seasons as to result in great injury to grasses. In most cases this compacting is due either to lack of organic matter or inefficient drainage, especially the ill effects of intermittent wet and dry conditions resulting from standing surface water or soggy conditions following rains. Many of the silt loams have a marked tendency to compact, and the cause here seems to be mainly deficiency in organic matter and lime.

ADAPTABILITY OF THE HEAVY OR CLAYEY SOILS TO LAWNS AND LAWN GRASSES.

Clay soils contain usually more than 50 per cent of total silt and clay, at least 30 per cent being clay. Clay soils, when productive, usually make very strong lawn soils, giving a dense sod, and in the regions suited to Kentucky bluegrass (*Poa pratensis*) excellent lawns consisting wholly of this most desirable of lawn grasses are easily obtained. The clay soils are usually, however, more difficult to prepare for lawn purposes, as the handling of the soil requires greater care than the more loamy soil to obtain a good physical condition at the time the seed is started. Liming is often desirable to help loosen the texture and the plentiful incorporation of organic manure is almost a necessity. In very heavy clays it will often prove advantageous to incorporate a loam or sandy loam with the first few inches.

Average mechanical analyses of some clay soil types.

Soil type.	Percentage composition.						
	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Houston clay [a]	1	2	2	9	11	41	32
Penn clay	1	3	.4	8	6	44	34
Cecil clay	3	7	6	18	11	26	30

[a] Local names applied when soil was first encountered in the soil survey and used for this definite soil wherever found in subsequent surveys.

Clay loam soils, like clay soils, contain more than 50 per cent of finer particles, but the clay particles are less in amount, usually from 20 to 30 per cent, and the silt less than 50 per cent. A well-drained and carefully handled soil of this texture is well suited for the establishing of an excellent greensward. It is retentive of moisture in amounts decidedly favorable to a good growth of grass. In the establishing of lawn soils by hauling from a distance or by mixing of soils, well-drained clay loams give good results, especially for mixing with sandy soils.

Average mechanical analyses of some clay loam soil types.

Soil types.	Percentage composition.						
	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Decatur clay loam	1	4	4	10	10	45	26
Dunkirk clay loam	2	4	3	12	14	36	29

Silt loam soils contain more than 50 per cent of silt and less than 20 per cent of clay. Many of the silt loams are ideally adapted to lawn making, but they must have good drainage and be liberally supplied with organic matter.

Average mechanical analyses of some silt loam soil types.

Soil type.	Percentage composition.						
	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Miami silt loam	0	1	1	2	8	73	15
Hagerstown silt loam	1	3	1	3	5	69	18
Dekalb silt loam	1	3	2	6	9	62	17

Loam soils contain less than 50 per cent of silt and less than 20 per cent of clay, but always more than 50 per cent of finer particles. A productive loam, that is, one having good drainage and containing sufficient organic matter to maintain a good loamy tilth, with a good permeable subsoil, neither excessively sandy nor clayey, will make a good lawn. When hauled in, it must be done with due consideration of the nature of the soil or filling already in place, as this becomes its subsoil.

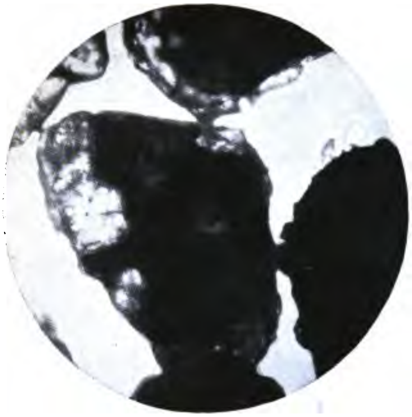
Average mechanical analyses of some loam soil types.

Soil types.	Percentage composition.						
	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Miami loam	2	7	7	12	11	46	15
Ontario loam	2	4	3	14	20	39	18
Sassafras loam	2	10	11	15	8	42	12

All of these heavier soils, especially those derived from limestone north of Washington, D. C., and somewhat farther south in the upland Piedmont region, are, as a class, usually suited to Kentucky bluegrass (*Poa pratensis*), the best of the lawn grasses in color, permanency and character of growth, although in individual soils it may fail in part or entirely, as it is sensitive to certain soil conditions. North of Tennessee, redtop (*Agrostis alba*) mixes well with Kentucky bluegrass, stands hard usage and hot weather, frequently growing where bluegrass fails. An association of white clover (*Trifolium repens*) with bluegrass should here be mentioned, as it is frequently observed that under certain soil conditions where bluegrass does not do well the association with white clover is very beneficial to the growth of the grass. This association is very marked in the region between the North and South, as in the neighborhood of Washington, D. C., where bluegrass by itself is very difficult to grow, but in association with white clover it does very well on good soils. On droughty soils, as some of the sandy loams, Canada bluegrass (*Poa compressa*) does very well in the East and North, but, owing to its superior resistance to drought and extended periods of hot weather, it can probably be used farther south than Kentucky bluegrass. These two grasses can be used to advantage in combination in some cases, as, for example, on poor clay and gravel soils which become at times extremely dry. The two grasses, however, do not blend well and in general grow in patches by themselves. While Kentucky bluegrass without doubt makes the most desirable lawns, its slow development and the fact that it is sensitive to soil and climatic conditions usually make it desirable to use mixtures of this with the other grasses which are usually quicker in growth, preferably Italian rye grass (*Lolium multiflorum*), thus giving a fair lawn even in the first year. If the soil conditions are suitable for the bluegrass, this will eventually take full possession of the ground, so that the other grasses are in no way a drawback to the establishing of a good, permanent bluegrass lawn where soil and climate are suitable. A frequent weed in bluegrass lawns of the North is Bermuda grass (*Cynodon dactylon*), which makes unsightly spots with the first coming of frost. In the South, where bluegrass does not usually do well, Bermuda becomes the chief lawn grass. The southern soils include a wide range of texture, having a widely different origin, particularly the well-drained members of the Cecil series of the Piedmont province, as well as the widely distributed and important soil types of the Atlantic and Gulf Coastal Plains.

ADAPTABILITY OF THE LIGHT OR SANDY SOILS TO LAWNS AND LAWN GRASSES.

Coarse sandy soils contain more than 25 per cent of coarse sand and fine gravel and less than 50 per cent of any other grade. The



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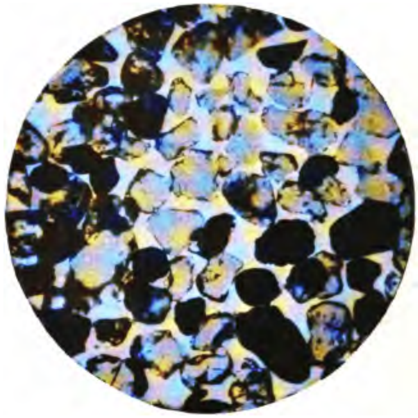

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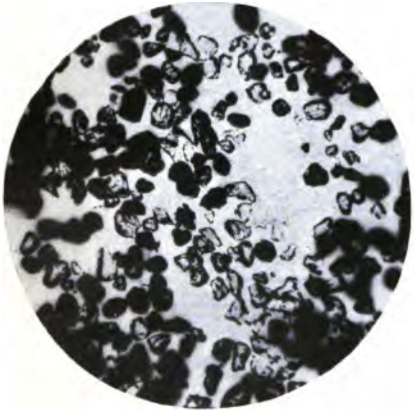

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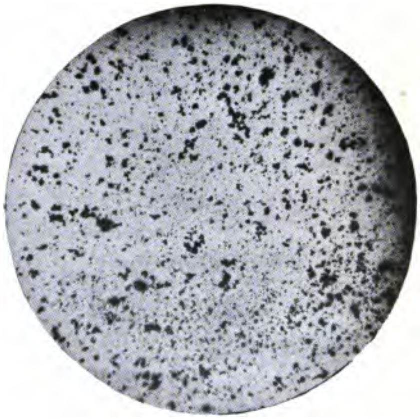


6.

PHOTOMICROGRAPHS SHOWING THE RELATIVE SIZES OF THE VARIOUS SOIL PARTICLES FROM THE COARSE GRAVEL TO THE SILT, THE CLAY BEING TOO FINE TO PERMIT OF BEING SEEN UNDER THE SAME MAGNIFICATION (32 DIAMETERS).

[The light-colored particles are usually crystals of quartz or pure sand, the dark-colored particles are other minerals containing the potash, calcium, magnesium, phosphate, iron, manganese, etc. 1, gravel; 2, coarse sand; 3, sand; 4, fine sand; 5, very fine sand; 6, silt.]

FIG. 1.—RELATIVE AMOUNTS OF DIFFERENT SIZED PARTICLES COMPOSING A CLAY SOIL.

[Soils of this texture, when productive, usually make very strong lawn soils, giving a dense sod, and, in the regions suited to Kentucky blue-grass, excellent lawns consisting wholly of this most desirable of lawn grasses. They are, however, more difficult to prepare for lawn purposes than the loamier soils. 1, fine gravel; 2, coarse sand; 3, medium sand; 4, fine sand; 5, very fine sand; 6, silt; 7, clay.]

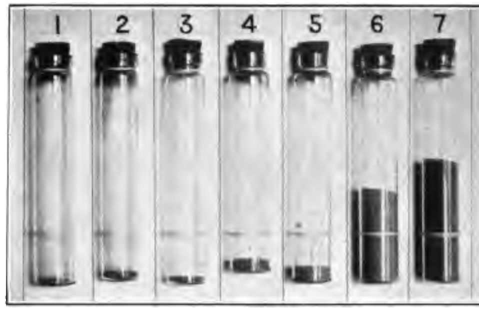


FIG. 2.—RELATIVE AMOUNTS OF DIFFERENT SIZED PARTICLES COMPOSING A LOAM SOIL.

[A productive loam, with suitable subsoil, will always make a good lawn. The loam is much looser than the clayey soils. The strongest soils are those having a clay subsoil. 1, fine gravel; 2, coarse sand; 3, medium sand; 4, fine sand; 5, very fine sand; 6, silt; 7, clay.]

FIG. 3.—RELATIVE AMOUNTS OF DIFFERENT SIZED PARTICLES COMPOSING A SANDY LOAM SOIL.

[Soils of this texture make very good lawns, and where underlain by a clay or clayey subsoil and having a high content of organic matter, rival the heavier soils for adaptability to lawn grasses. 1, fine gravel; 2, coarse sand; 3, medium sand; 4, fine sand; 5, very fine sand; 6, silt; 7, clay.]

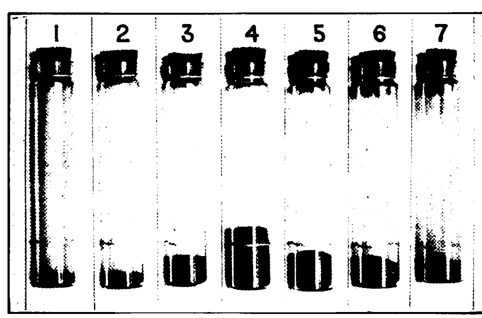
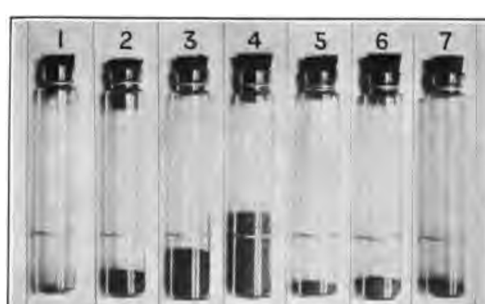


FIG. 4.—RELATIVE AMOUNTS OF DIFFERENT SIZED PARTICLES COMPOSING A SANDY SOIL.

[Soils of this texture are not well suited for lawn purposes, although certain grasses will grow, and where necessary can be used as soil binders, but the result produced can hardly be called an ornamental lawn. Its low water-holding power is its chief drawback. 1, fine gravel; 2, coarse sand; 3, medium sand; 4, fine sand; 5, very fine sand; 6, silt; 7, clay.]



finer particles of silt and clay are present in small amounts and the total of these is never greater than 20 per cent. Soil of this texture is unsuitable for lawn purposes, although certain grasses will grow and where necessary can be used as soil binders, but the result produced can hardly be called ornamental. It is too dry and loose for lawn purposes.

Fine sandy soils contain less than 25 per cent of the coarser grades of soil particles and more than 50 per cent of fine sand. The content of clay and silt is small in amount, but may be as large as in the coarse sandy soil described above; the principal part is made up of fine and very fine sand. A fair lawn may be established on soils of this class by paying special attention to the preparation of the soil by the introduction of manure or green manure, together with bone phosphates and lime in some cases and copious watering during dry seasons. With a clay or clayey subsoil a really good and permanent lawn can be established on such sandy soils without great difficulty, especially when a mixture of suitable grasses is used. Its low water-holding power is its chief drawback. Top dressings of well-rotted stable manure and other fertilizers from time to time are requisite for good results. Lime as a top dressing is also often desirable on sandy soils.

Average mechanical analyses of some fine sand types.

Soil types.	Percentage composition.						
	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Norfolk fine sand	0	3	10	56	15	11	5
Dunkirk fine sand	0	3	11	49	23	9	5
Wheeling fine sand	0	2	17	53	14	9	5

Sandy loam soils contain more than 25 per cent of fine gravel, coarse and medium soil grains, and from 20 to 50 per cent of total silt and clay. A considerable portion of the sandy loam is made up of fine and very fine sand. Soils of this texture make very good lawns when well drained, well supplied with organic matter, and where underlain by a clay or sandy clay subsoil, sometimes even rivaling the clay loam or silt loam in adaptability to lawn grasses. When low in organic matter the deficiency must be made up. Stable manure, forest mold, green crops plowed under, especially the legumes, afford very desirable material for supplying needed organic matter. Lime is frequently desirable and often necessary in the soil preparation and as a later top dressing. Bone phosphate should be used in preparing the soil and may be later used as a top dressing.

Average mechanical analyses of some sandy loam types.

Soil types.	Percentage composition.						
	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Sassafras sandy loam	2	10	14	20	9	34	11
Greenville sandy loam	1	13	17	32	9	16	12

Fine sandy loams contain less than 25 per cent of fine gravel, coarse and medium grains, or more than 50 per cent of fine sand. The amounts and limits of silt and clay may be the same as in sandy loam soils. Soils of this texture are very similar in their adaptability to lawn making and have even a greater water-holding power.

Average mechanical analyses of some fine sandy loam soil types.

Soil types.	Percentage composition.						
	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Orangeburg fine sandy loam	1	3	6	39	24	19	8
Norfolk fine sandy loam	1	3	5	38	24	21	8

With the exception of the sandy and fine sandy loams these lighter soils are not so well suited for bluegrass lawns as are the heavier soils. The binding grasses, as well as those capable of growing under less moist conditions, are much more suitable than the bluegrass. The redtop (*Agrostis alba*), which mixes well with bluegrass, being similar in color, is especially valuable on sandy soils, as it often grows where bluegrass fails. The Rhode Island bent grass (*Agrostis vulgaris*) with its close, turf-forming habit is especially well adapted to the sandy soils and grows well under moist or dry conditions. For very sandy seaside soils, besides the Rhode Island bent, beach grass (*Ammophila arenaria*) should be used. The latter will hold drifting sands and can therefore be used on the sand hills of the Southern States, the seacoast, sand dunes, embankments, and cuts through loose and dry sandy soils. For the latter purpose Bermuda grass is also well suited southward, as it will grow on poorer soils and stand heat and drought. The Bermuda grass, as already mentioned, is admirably suited for lawns on the sandy soils of the South, where bluegrass can not be grown. This grass stands out strikingly as a good lawn grass for the fine sandy loams. Another grass which has been received with favor in this region, especially from Charleston southward, is the Korean grass (*Osterdamia matrella*), a maritime grass from Asia and Australia. In the Southern States carpet grass (*Paspalum compressum*) and St. Augustine grass (*Steno-*

taphrum secundatum, *S. Americanum*) make good lawns on soils even lighter in texture than the fine sandy loams. The St. Augustine grass is even better than Bermuda grass for extreme hot climates, such as Florida or even the West Indies. Good winter lawns of Italian rye grass (*Lolium multiflorum*) are easily maintained in the South Atlantic and Gulf States on the sandy soils.

STONY OR GRAVELLY SOILS.

In addition to the soil classes described above, many soils contain larger particles, which if of small size are called "gravel" and if of larger size are called "stones," so that in the soil classification it is possible to have a gravelly sand, gravelly loam, or gravelly clay, and likewise stony members of the various classes. The presence of a moderate amount of gravel or small stones in any of the soils suitable for lawn purposes, such as clay loam, loam, or sandy loam, does not materially impair their adaptability for the establishing of a greensward. Of course it is essential that in this case the gravel or small stones be natural to the soil and not rubbish which has been introduced by filling in and only imperfectly incorporated with the soil.

TEXTURE OF SOILS UNSUITED FOR GOOD LAWNS.

Soils having a texture which does not fall properly within any one of the classes above enumerated are frequently found, among them many that are entirely unsuited for the production of a good lawn. Normal soils of the above classes usually contain graded amounts of nearly all of the particles, the difference being usually one of degree only. Occasionally there are found abnormal soils in this respect—that is, soils which consist almost wholly of one or two sized particles, for instance, pure sands or clays. Such soils are seldom of a texture to give the proper physical condition necessary to supply and retain moisture and promote the necessary soil processes for successful lawn culture. An individual illustration of a texturally unbalanced soil is found in the case of a soil on which many futile attempts have been made to establish a lawn. This particular soil has the following texture:

	Per cent.		Per cent.
Fine gravel	2.5	Very fine sand	2.3
Coarse sand	32.5	Silt	26.9
Medium sand	12.1	Clay	15.5
Fine sand	8.0		

This soil is peculiar in that it possesses relatively large amounts of coarse and of fine material, but only a small quantity of medium-sized particles. The result is that the soil packs firmly and is naturally dry and unsuited for a good turf.

Other illustrations among the sandier soils are to be found in those that consist almost entirely of two or three grades of particles. The coarse beach sands are often of this character; hence especial care is necessary in starting and maintaining lawns on such soils. The following analysis illustrates such a condition:

	Per cent.		Per cent.
Fine gravel	11.5	Very fine sand	1.0
Coarse sand	29.1	Silt	0.2
Medium sand	17.1	Clay	0.1
Fine sand	40.8		

A normally productive soil, though predominantly a clay, fine sand, or coarse sand, contains also some of the other grades, thus giving soils of well-balanced texture, whereas the soils above mentioned have in this respect an abnormal texture and consequently an abnormal physical and chemical behavior toward growing plants, in this case grass. Such abnormal soils must be avoided or made over by incorporation of material of suitable texture to bring about a more balanced condition. In mixing soil materials, however, it is again essential that they be texturally not too widely separated. Thus, for instance, never mix a heavy clay with a distinctly sandy soil, but rather add a loam to the sand to attain the proper texture of the mixture.

INFLUENCE OF TEXTURE ON THE STRUCTURE OR TILTH OF LAWN SOILS.

The texture of the soil, as already mentioned, is largely controlled by the proportions of the various-sized particles which make up the soil. The texture of a soil determines its water-holding power; thus, for instance, the sandier soils hold on an average not over 4 per cent of moisture, while the clay soils will hold as much as 20 per cent. With this difference in moisture capacity in the various soils, there is a corresponding difference in the amount of air space, composition of the soil atmosphere, and in the oxidation, which is usually more rapid in the sandy soils than in the clay soils. The mere mechanical composition of the soil does not, however, determine directly any of these factors; they are determined rather by the arrangement or structure which the particles assume in the soil. This arrangement or structure depends upon the texture, the amount of organic matter and the presence of other chemical and physical factors. These factors aid or hinder the formation of proper structure or granulation of the soil particles. The individual and ultimate soil particles are grouped in the soil in composite clusters and it is these composite clusters which cause a variation in pore space and consequently in water-holding power, rate of oxidation, efficient or defective drainage, in one and the same soil, according to the methods of soil management employed, fertilization with inorganic and organic manures, liming, crop succession, freezing and thawing, and other factors; all these influence the structure or tilth of the soil, though not necessarily the texture or mechanical composition. In other words, the composition in various-sized particles determines to a large extent the possibility of influencing the tilth and structure by soil management and soil amendments. This generalization is illustrated by the fact that when a soil is thoroughly puddled, the structure of the soil is completely changed; the individual particles which determine the texture are all present, but in such form as to give the least space between the particles. These facts again illustrate the importance of a proper texture for a lawn soil, for it is difficult to get the desired granulation in soils which are not properly balanced in the content of the various-sized particles. Usually soils which have this unbalanced texture are difficult to manage and are likely to assume unfavorable structural conditions, interfering with the permanent granulation so necessary for a good and productive soil in which proper aeration, drainage, oxidation, and other chemical changes can take place and in which microorganisms can perform their proper and necessary functions.

THE SUBSOIL, ITS INFLUENCE ON TOP SOIL AND LAWN.

A soil can not be judged for lawn purposes simply by the visible surface, or top soil as far as it is ordinarily cultivated or turned by plow or spade. Soils are underlain at different depths in different types by a distinctly different soil layer known as the subsoil. In shallow soils this subsoil, usually different in texture, but not necessarily so, is sometimes within a few inches of the surface and is indeed often touched by plow or spade, and thus gradually the soil itself may be deepened and changed in texture. In other cases the soil is quite deep, often many feet, and in arid regions this change in soil material as one goes downward is often not observable at all.

The depth of the surface soil is very important and variable. Soils of widely different agricultural value owe this often to difference of depth alone. The fact that the nature of the subsoil has an effect on the productiveness and suitability of soil for lawn purposes has already been mentioned. Those soils having a clay subsoil are usually stronger soils and better able to maintain a good lawn than those having sandy subsoils. In the sandier soils the better results are always obtained where a good clayey or even clay subsoil occurs.

In figure 1 are shown three-foot profiles of soil types illustrating different depths of surface soil and nature of subsoils as actually encountered under natural conditions.

The texture of the subsoil is fully as important as the texture of the soil, although the requirements of a good subsoil are usually somewhat different from the requirements of a good top soil. An impervious clay, which usually means bad texture, is utterly unsuited for any soil, and in fact soils occurring naturally above such subsoils are themselves poor, but can often be made most productive by laying drainage tiles in the subsoil. The character of the subsoil, its tex-

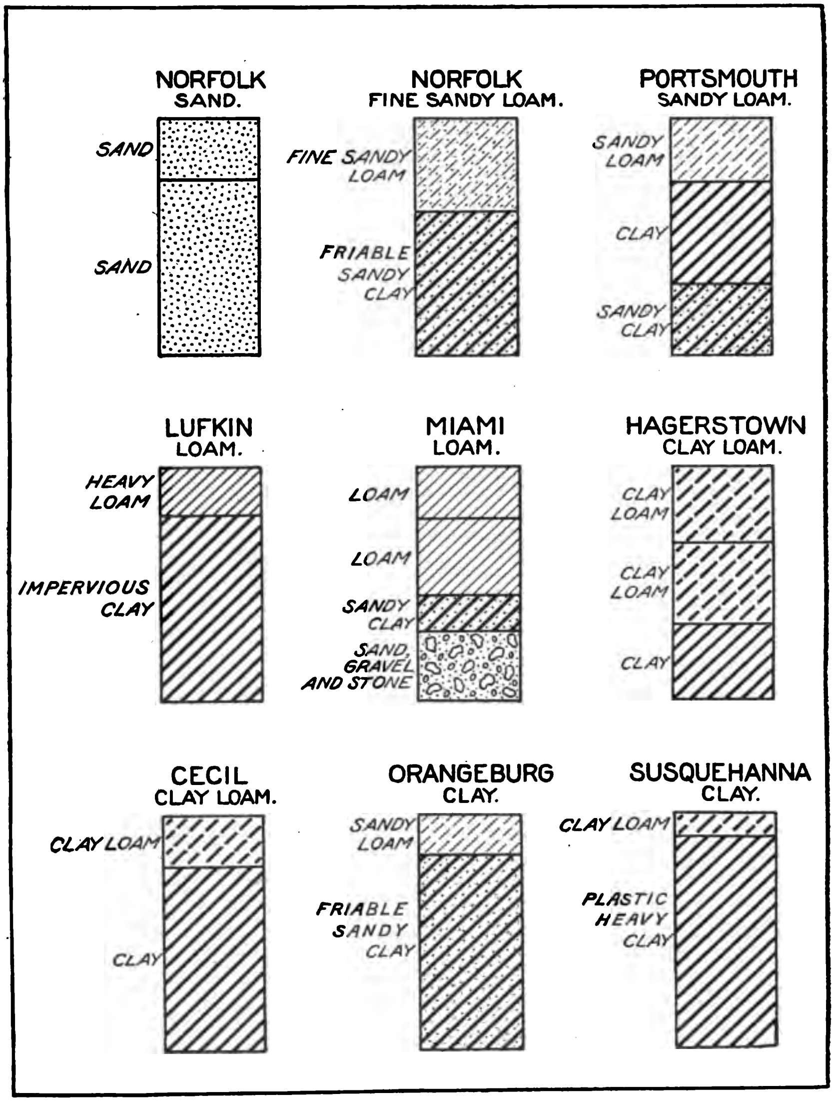


FIG. 1.—Three-foot profiles of soils, illustrating different depths of surface soil and nature of subsoils.

ture, and its distance from the surface are often vital criterions of the natural productiveness and suitability of soils, and hence these factors must also receive consideration in the establishing of a lawn, whether it be by filling in of soil materials or on a soil in its natural position.

The subsoil of a good lawn soil should, in the first place, be not too near the surface; that is, the soil itself should be a deep soil, never less than 6 inches and preferably as deep as 12 inches or more, for it must be remembered that a subsoil even when good as a subsoil is nevertheless a poor substitute for a surface soil, as will be brought out more fully in another place. The subsoil should resemble the surface soil in its general character. It should be heavier in texture when underlying sandy soils, but may be of lighter texture in the case of the heavier surface soils. The subsoil should be moist at all times, yet permit of good drainage. It should retain considerable amounts of water during the wet season and later during dry spells be able to give it up to the surface soil and roots therein. By virtue of a close and firm texture it can draw moisture from considerable depths. If the subsoil is of bad texture, such as an impervious clay, the drainage is bad and the soil consequently cold and wet, unmanageable, and unproductive, or if it consists of loose, sandy material it will be too leachy and consequently too dry, especially during droughts, because no water will be stored in it nor drawn up through it from greater depths. Other bad subsoil conditions, involving bad drainage, are various hardpan formations. These are usually layers of soil cemented together by calcareous or ferruginous material and are found in certain regions in large sheets or pockets, often immediately below the surface soil, thus acting as an effectual barrier to the movement of moisture, either downward or upward. Under such conditions, which are fortunately rare in soils to be used for lawns, grass can not be grown any more than on a cement or other sidewalk buried a few inches under the ground. Unfortunately lawn builders, through carelessness, indifference, or ignorance, sometimes do cover up such old sidewalks and consequently the grass always dies out even if the surface soil is of the best and the difficulty is not found until an examination of the subsoil condition is made through intention or accident, as in the case of the illustration shown in Plate III, figure 1.

The subsoil can be readily brought to the surface for examination by means of the soil auger. This consists of a 1-inch auger from which the screw portion is broken off and the square end on the shank which fits into the brace is likewise cut off and threaded with standard thread so as to connect with a three-eighths-inch gas pipe by means of a coupling. The gas pipe can be in sections of 1 foot each and as many as desired be joined together. The upper one is provided with a T coupling and two shorter pieces of pipe form the handle. Such an instrument is shown in figure 2. By screwing this into the soil and pulling out the auger with the core in place, a soil sample can be obtained from any desired depth. Such an instrument entirely prevents the disfigurement which would be unavoidable if a larger hole had to be dug in a lawn, and moreover is so simple in its operation that a large number of places can be examined in different portions of the lawn or park. The manner in which the auger penetrates the different layers of material gives to the operator at once an indication of soil conditions. For instance, a good deep soil of uniform texture is at once distinguished from a shallow soil underlain by a stiff wet clay, or a hard dry soil, or loose sandy soil, or rubbish from filling in with bricks, cans, wood fragments, etc. Moreover such an examination in a lawn already established will reveal to the expert good or bad drainage conditions in the subsoil and also whether it be a made or a natural soil formation.

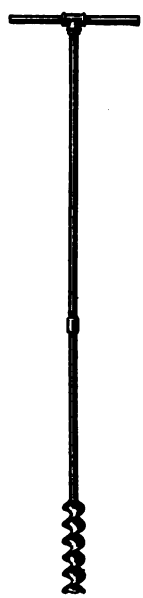


FIG. 2.—Soil auger for collecting soil samples and useful in exploring subsoil conditions in lawns.

There is no doubt that in certain sections of the country certain subsoils are harmful when incorporated in a soil, and that while deep plowing is desirable, it is unsafe, after shallow plowing has been carried on for years, to run the plow down and turn up a great mass of subsoil and incorporate this with the soil. In a great many cases it has taken several years to restore the original fertility of the soil. A subsoil should never be used in lawn building without being covered 6 to 12 inches with a good surface soil.

In this connection another observation may be cited here which illustrates this point rather well. A railroad embankment was thrown up over a lawn. The lawn had flourished many years, located as it was in one of the fine grass sections. This embankment was built across one end of the lawn and remained there for a number of years. Then the railroad was abandoned and that portion of the embankment which covered the lawn was removed, exposing the surface of the old lawn to the action of the air and sunlight, but it was almost impossible to get grass to grow again. Attempts to grow grass were made for several years on this soil which had been to all intents a subsoil for a number of years by being covered over.

SOIL TYPES, SERIES, AND PROVINCES.

Lawns are not developed with equal success on all soils. This is due to the natural differences in soils as a result of their different formation, different texture, relation to subsoil, and climatic conditions under which they occur and which also affect directly the grasses themselves. Different grasses are suitable for lawns under climatic and soil conditions under which other grasses perish, or at best do not reach that development necessary for the formation of a dense turf. Attention has already been called to the influence of the texture of the soil on lawn building and the above statement also emphasizes that thorough consideration be given to the soil region or province in which a lawn is to be established, or the soil series from which the lawn soil is to be obtained, especially where the soil is to be hauled from the country to the city for the establishing of good lawns, parks, or other public grounds.

Soils differ one from another, as individuals differ, in their characteristics, peculiarities, and adaptabilities; they differ further as nations differ, or still more profoundly, as one race from another race. The chief factors in this difference between soils has been brought about by the formation of soils from different geologic materials acted upon by different natural agencies, such as climate, humid, arid, and semiarid; glaciers; wind, water, in lake, ocean, or river. Due to such great differences in the soil-forming agencies upward of 700 individual soil types have been found by soil surveys in the United States. These fall naturally into larger groups known as soil series and these again into still larger divisions known as soil provinces.

The chief soil provinces comprise (1) the soils of the Atlantic and Gulf Coastal Plains; (2) the soils of the Piedmont Plateau; (3) the soils of the river flood plains; (4) the soils of the Appalachian mountains and plateaus; (5) the soils of the limestone valleys and uplands; (6) the soils of the glacial and loessial regions; (7) the glacial lake and river terraces; (8) the residual soils of the western prairie region; (9) the soils of the Great Basin; (10) the northwestern intermountain region; (11) the Rocky Mountain valleys, plateaus, and plains; (12) soils of the arid southwest; and (13) the soils of the Pacific coast. Each of these provinces contains a number of soils which possess certain characteristics of formation, depth of soil, character of subsoil, color of soil and subsoil, and other characteristics, giving rise to distinct soil series; as, for instance, the Cecil series of the Piedmont Plateau province, characterized by red subsoils with gray to red surface soils; the Chester series, characterized by yellow subsoils and gray or brown shallow surface soils; and the Penn series, characterized by Indian or purplish-red color. In the Atlantic and Gulf Coastal Plains province are found among others the Norfolk series, which consists of light-colored sandy soils, underlain by yellow sandy or sandy clay subsoils; the Portsmouth series, consisting of dark-colored soils with yellow or mottled gray sandy or sandy clay subsoils; and the Orangeburg series comprising light-colored soils with red, sandy-clay subsoils. Similarly in the Appalachian Mountain and Plateau province occurs the Dekalb series, characterized by brown or yellow soils with yellow subsoils, and the Upshur series having an Indian-red color. Similarly, series are determined by other factors than color, such as the character of the parent formation or method of origin. In each series occur the various classes based on texture, as explained in a previous section, and this together with the series characteristic determines the type. Thus there are the Cecil clay, Cecil silt loam, Cecil loam, and other classes, there being 10 members in this series. In the Penn series there are seven members, and in the Chester four members, thus illustrating that not all classes have been found in any one series. The various series and members of the series, the soil types, have widely different agricultural values and show a wide range of adaptability to grass growing or lawn making, as already pointed out.

IMPORTANCE OF SOIL FLUID.

It is through the medium of the soil fluid that the growing grass obtains the products of solution of the soil materials, inorganic and organic, both good and bad, if the latter be present. From the soil fluid it obtains the potassium, calcium, magnesium, phosphorus, nitrate, and other elements necessary for its proper functioning. These it removes from the soil fluid by the process of absorption by the growing root, and when the soil sanitation is good this absorption proceeds in a normal manner, but when it is imperfect, due to bad drainage or accumulation of products unfavorable to growth, the absorption of the plant is seriously interfered with. Most important, however, is the water of the soil fluid itself, for this is absolutely necessary for carrying on all plant processes and also enters into nearly every necessary compound produced in the life activities of the grass. It is the plant's chief source of hydrogen and oxygen, which, together with carbon obtained from the carbon dioxide of the air, forms the larger part of the plant's total dry substance. The water, moreover, forms the larger part of the grass itself when green. These facts tend to emphasize the great importance of soil fluid to the growing grass and further show the absolute dependence on this for the establishing of a good growth of grass. The importance of the soil condition and texture in influencing the amount and movement of this soil fluid becomes, therefore, of paramount interest, as through it the life of the lawn is sustained and maintained. The greatest drawback to the establishing of a good lawn is an inadequate water supply during periods of drought and the chief function of a good lawn soil is to furnish an adequate water supply, to moderate excessive rainfall by good drainage, and yet hold sufficient water to allow the lawn to live through periods of drought.

EFFECT OF TEXTURE ON AMOUNT AND MOVEMENT OF SOIL FLUID.

The roots of lawn grasses are comparatively close to the surface and do not penetrate more than a few inches into the soil except where excellent soil conditions exist. The greater the depth of good surface soil the deeper will the roots penetrate and consequently the greater the amount of soil fluid directly available. Ordinarily, however, the soil accessible to the roots will even in a soil with good water-holding power, not contain enough water to last through a considerable drought, and it is therefore necessary that the soil be able to draw moisture from lower-lying strata. A heavy retentive subsoil acts, as it were, as a soil-fluid reservoir to supply the surface soil with water during dry spells.

The movements of soil fluid are chiefly upward and downward, any lateral movement being extremely slight. The downward movement occurs as the result of rainfall, melting snow, or other addition of water at the surface. This downward movement is usually rapid and varies according to the texture and structure of the soil, which also determines the amount of water retained in the soil. Later, by evaporation from the soil or through transpiration by the grass, this moisture in the soil is gradually dissipated into the atmosphere, and a movement of soil fluid is set up within the soil whereby moisture moves from the wet subsoil into the surface soil through the capillary spaces made by the soil grains or aggregates of grains. In loose sandy soils the moisture descends, reaches the water level below the soil and subsoil, and begins its movement laterally from the soil as seepage waters, finding outlets into ditches, streams, and other water courses, comparatively little being retained in the moisture films about the sand grains. During dry periods this retained moisture is soon depleted, and owing to the coarseness of the grains the movement upward is not sufficient to keep up with the demand in the surface soil, the connection with the subterranean water is broken, and a dry subsoil is the result, thus causing an impoverishing of the lawn with ultimate parching and dying out of the grass during the summer months.

In the heavier soils the water does not descend so rapidly nor so completely, and considerable amounts are retained and when required again move upward to the surface soil. Moreover, the connection between the soil fluid and the low-lying water level is not so easily severed so that water from considerable depths can be drawn upon to supply the needs in the surface soil.

GOOD DRAINAGE ESSENTIAL.

In this beneficial property of the heavier soils and subsoils to retain moisture and offer resistance to its free passage lies on the other hand a danger. When this resistance, by virtue of too close a texture or lack of structure, becomes excessive the soil becomes, as it were, "water-logged," producing a wet, cold soil, without aeration and proper life. There is an almost total arrest of the normal functions of the soil and a substituting therefor of an abnormal condition, resulting in the formation of compounds inimical to the growth of grass, so that it dies as the result of impoverished growth and impoverished air supply to the roots. Such a condition can be alleviated or eliminated by proper drainage, such as may be secured by the laying of tiles in the subsoil, whereby the flow of water is facilitated, the air again penetrating, and a normal oxidation and functioning of the soil is brought about. The application of lime to aid in forming the clay particles into larger groups, thus giving large spaces between these groups, through which the soil fluid can then move with greater freedom, is often resorted to and should never be omitted in making lawns on soils having very stiff subsoils. Hardpan formations and other natural hindrances to the movement of water must also be broken up by subsoiling or other means, as good drainage, like a good water supply, is absolutely essential for a healthy greensward.

The presence of bricks, flat tins, boards, and other coarse building débris found in nearly all small lawns in the city acts also very detrimentally to the proper movement of soil fluid. The downward movement of water is not seriously impeded by such materials and is probably even facilitated. The moisture moves downward until it encounters a brick, for instance, at a distance of 3 or 4 inches below the soil level. The water meets with no difficulty in getting to the edge of the brick and then goes nearly straight downward, thus leaving the soil immediately below the brick unsupplied with this new water influx. Now, when the opposite movement of soil fluid begins the water moves upward, but leaves the soil immediately above the brick, which has in the meantime dried out, unsupplied with moisture, so that the grass suffers and dies out during a critical dry spell. Bad spots in small city lawns are more often than not found to be due to some such impediment to the movement of capillary water.

INFLUENCE OF ORGANIC MATERIAL IN LAWN SOILS.

ORGANIC MATTER NECESSARY TO MAKE A LAWN SOIL OF GOOD STRUCTURE.

The organic materials of the soil are very important in that they make soil out of what would otherwise be only a rock powder or sand. The organic matter is the great promoter of proper structure of the particles to form an arable soil; its influence in the formation of loamy friable soils of good texture and structure is well known. By its presence and the changes which take place during its decay, the water-holding power of a soil is greatly increased, and hence its presence in lawn soils is especially desirable. It is, however, in the lawn that it is most difficult to introduce organic matter into the soil, and it becomes imperative, therefore, that the lawn soil be made as rich in this important soil ingredient as is possible before planting, i. e. when the lawn soil is first prepared. Later, when the lawn is established, organic matter can only be introduced into the soil in the soluble material leached from manure and other surface applications, and the beneficial effects in loosening up soils, by influencing their structure produced by the decay of the insoluble materials of the manure, are therefore entirely absent. The decay of manure is usually more rapid in sandy soils than in clay soils, another factor which makes the sandier soils less desirable for lawns. Some of these effects of organic matter on soils and the influence of bacteria, molds, and other life forms in suiting these organic materials to the best uses of the grass have already been mentioned.

PRESENCE OF HARMFUL ORGANIC MATTER.

In addition to the physical effects the organic materials have a chemical and physiological effect on the lower life in the soil as well as on the grass. Some of the products of change of these organic materials are doubtless directly beneficial to bacteria, promoting their activities, and also directly beneficial to the growing grass, as is indicated by recent experiments on the utilization of certain organic compounds by plants. It is likewise certain that some conditions are directly harmful to grass, preventing its best development, interfering with its root growth and root absorption of soil nutrients to such an extent as to make the successful growth of grass under such conditions impossible. This is readily shown by the following experiment:

A water extract of an unproductive lawn soil was made by agitating one part of soil with three parts of distilled water for 3 minutes and after standing 20 minutes filtered through an unglazed porcelain filter in an apparatus of special design. In this manner an absolutely clear extract of the soil was obtained, containing such soil materials as are readily soluble—potassium, calcium, magnesium, phosphate, nitrate, and other salts beneficial to plant growth, together with soluble organic materials. Plants were then grown in the watery solution of the soil material and a similar culture prepared for comparison in which the plants are growing in pure distilled water. Since the soil extract contained plant nutrients, whereas the distilled water contained none, the growth in the extract should under normal conditions have exceeded the growth in the distilled water, but this was not the case in the extract prepared from this unproductive lawn. It should be here stated that good soils give good extracts and poor soils poor extracts, showing that the property of fertility or infertility is imparted by the soil to its extract. This effect of the extract from the unproductive soil, in spite of the presence of plant nutrients, to produce a poorer growth than does pure distilled water can be explained by the presence of an injurious body in the extract, interfering with the normal development of the plant. If now this extract is shaken with carbon black, prepared similar to ordinary lampblack by condensing divided carbon on cooled surfaces in the combustion of natural gas, this harmful body is removed from the solution by virtue of the power which such carbon black possesses to absorb organic materials. On filtering off the carbon black, and with it the absorbed harmful ingredient, the extract becomes a very good medium for plant growth. These effects are shown in Plate IV, figure 1.

Another experiment with soil and carbon black was made as follows: A layer of moist carbon black was covered with a layer of moist unproductive soil and this in turn by a layer of moist carbon black. In this experiment the soil moisture could circulate from the soil to the carbon black and back again and thus gradually the soil fluid would be freed of any injurious compounds by absorption in the carbon black. At the end of a day or two of this interaction the soil was freed from the carbon layers, plants were grown in it, and when compared with soil not so treated a very marked improvement was shown, again indicating that a harmful body was originally present and had been removed in whole or in part by this carbon black treatment.

A third experiment showed this still more strikingly. An unproductive lawn soil, in this case from a place in a lawn near trees where grass growth was very poor compared with the remainder of the lawn, was put up in a large pot. This lawn condition is shown in Plate III, figure 2. In the middle of the pot was buried a smaller, porous earthenware pot filled with moist carbon black; the lower opening being completely stoppered, the rim projecting above the soil in the larger pot. In this way the only communication between the soil in the larger pot and the carbon black in the smaller pot was through the porous wall of the small pot, which would allow of an interchange of soil fluid, as in the preceding experiment. Lawn grasses were sown in the circle of soil between the rims of the larger and smaller pots. Another pot of exactly the same kind and arrangement with small pot was put up, except that the small pot in this control experiment was filled with the same soil instead of with carbon black. This was likewise sown with lawn grasses and both pots kept in the greenhouse under identical conditions. It was soon evident that the growth of the grasses in the soil purified by carbon black was better and at the termination of several weeks the grasses were cut and their relative weights were 100 in the untreated soil and 160 in the soil purified by the carbon black. Attention should here be called again to the fact that the carbon black merely absorbs the harmful materials and does not, therefore, permanently remove them from the soil, if the carbon black is directly added to the soil and allowed to become a part of it.

In some cases a leaching of the soil with water has brought about a marked increase in the productivity of the soil although by such leaching mineral plant nutrients were removed along with the substances hindering growth.

In the above experiments the object was to demonstrate the presence of harmful bodies in the soil and soil fluid, not to offer this as a means of soil purification. The practical elimination of such soil defects has not yet been completely worked out, owing to lack of knowledge of the nature of the compounds producing these harmful effects, but the remedial measures to be employed will be given later as far as the study of these compounds permits.

ISOLATION AND IDENTIFICATION OF HARMFUL COMPOUNDS IN LAWN SOILS.

Experiments like the above point strongly to the presence of harmful substances in soils of this kind, and the general behavior of the soil solutions indicate very strongly the organic nature of the compounds causing the difficulty. This led, therefore, to a study of the organic material of the soil in a manner and with a motive which had never before been used in soil investigations, with the result that a large number of compounds were obtained in a pure crystalline condition from soils and their chemical, physical, and physiological properties determined and studied.[a] Such investigations have thrown much light on the complex subject of soil fertility, but the intricacies of the investigations and their results need not be given here other than as they have a bearing on lawn problems. Suffice it, therefore, to say that among the compounds already isolated and identified are some containing hydrogen and carbon only; some, hydrogen, carbon, and oxygen; some, hydrogen, carbon, oxygen, and nitrogen; and some, hydrogen, carbon, oxygen, nitrogen, and sulphur; some compounds containing phosphorus being present also, but as yet unidentified. These compounds comprise representatives of the principal groups of organic compounds: Hydrocarbons, fatty acids, nitrogenous acids, alcohols, esters, fats, waxes, resins, carbohydrates, nitrogenous bases, and sulphur compounds. Among these are dihydroxystearic acid and picoline carboxylic acid, which are of especial interest in this connection, as they have both been found in unproductive lawn soils and both are harmful to plants. The picoline carboxylic acid is only moderately toxic and has not been encountered often, although this may in part be due to the experimental

[a] The Isolation of Harmful Organic Substances from Soils, by Oswald Schreiner and Edmund C. Shorey, Bul. 53, Bureau of Soils, U. S. Dept. Agr. (1909). Chemical Nature of Soil Organic Matter, by Oswald Schreiner and Edmund C. Shorey, Bul. 74, Bureau of Soils, U. S. Dept. Agr. (1910).

difficulties involved. The dihydroxystearic acid is more readily obtained and has been encountered in a number of poor lawn soils.

When, for instance, one of the poor lawn soils mentioned above as showing the presence of a harmful compound is treated with a weak solution of alkali, the latter dissolves an appreciable amount of the organic matter, a much greater quantity than pure water, and after making acid with acetic acid and filtering from the precipitate produced, the filtrate is extracted with ether and this on evaporation gives a nicely crystallized compound. This was chemically determined to be dihydroxystearic acid, a compound already known to science, but only as a laboratory product. A very weak solution of these crystals in distilled water or in a good soil extract was then used as a culture medium for plants; a control in pure distilled water or in a good soil extract being set up at the same time. The results were very definite and showed conclusively the harmful effects of the compound on plants. This is shown in Plate IV, figure 2, where the growth in the solutions containing the compound is scarcely more than one-half that in the pure culture. The roots are always stunted by this compound, become dark on the tips, and usually turn upward as if trying to get out of the unfavorable solutions. A study of the plant nutrients removed by the plants in the presence of the compound revealed the fact that the absorption of nutrients is very materially interfered with. The presence of fertilizer salts decreased the harmful effect, but did not overcome it entirely. This study of the action of fertilizers showed that nitrates were the most efficient in modifying the harmful effect of this compound as were also all other treatments which promote soil oxidation itself or oxidation by the plant roots in the soil.[b]

REMEDIAL MEASURES FOR ELIMINATION AND PREVENTION OF HARMFUL COMPOUNDS.

The dihydroxystearic acid is readily changed by oxidation to other compounds and is finally completely destroyed. Its very existence in soils depends therefore upon poor oxidation or aeration in the soil, and this effect is remedied by such soil treatments as promote oxidation. When the soil samples containing the harmful compound are kept in the laboratory or greenhouse under conditions of good aeration for a few weeks the compound disappears entirely and can no longer be detected by chemical means, the soil having also become greatly improved through this treatment.

Liming, drainage, and the application of good organic manures are the most potent factors in promoting oxidation in soils. Liming has been found to be very beneficial, aiding the destruction of harmful bodies of this nature, both by combining with them and also by

[b] Some Effects of a Harmful Organic Soil Constituent, by Oswald Schreiner and J. J. Skinner, Bul. 70, Bureau of Soils, U. S. Dept. Agr. (1910).

FIG. 1.—A BURIED SIDEWALK IN A LAWN.

[Lawn builders, through carelessness, indifference, or ignorance, sometimes cover up old sidewalks, and consequently the grass always dies out, even if the surface soil is of the best, and the difficulty is not found until an examination of the subsoil conditions is made.]

FIG. 2.—BARE PLACES UNDER MAPLE TREES.

[Grass failed to grow, although heavily manured, fertilized and reseeded each spring for years. The dark areas under the trees are the bare spots. The grass fails in spite of favorable moisture conditions. Shade may play a part, although immediately across the path, equally shady, grass grows well.]

FIG. 1.—THE TOXIC PROPERTY OF A LAWN SOIL.

[1. Grown in distilled water. 2. Grown in the lawn soil extract. 3. Grown in the same lawn soil extract after treating with carbon black.]

FIG. 2.—EFFECT OF DIHYDROXYSTEARIC ACID, A HARMFUL COMPOUND ISOLATED FROM A POOR LAWN SOIL.

[1. Grown in a solution of the harmful compound. 2. Grown in pure distilled water.]

oxidizing them to other less harmful or even beneficial compounds. Drainage also aids materially in two ways: First, it allows a freer access of air with deeper penetration of healthy roots, which in time promotes oxidation and thus aids the destruction of unfavorable organic matter; second, it will produce beneficial results by an actual removal of the harmful material in the drainage waters, as well as perhaps by eliminating the cause of its formation. The addition of good organic manures will also assist in the destruction of the compounds already in the soil. The introduction of easily decomposed organic matter causes greater bacterial activity and greater oxidation in the soil, so that through the inauguration of the processes of its own decomposition it has the effect of causing the change in the organic matter in the soil to proceed in a different direction from that which formerly existed. The fertilizer salts are shown by experiments to act in a very similar manner, inducing or quickening changes which take place without them only very slowly or not at all.

POSSIBLE ORIGIN OF THE HARMFUL COMPOUNDS IN SOILS.

Concerning the possible origin of the harmful compound obtained in lawn soils as described above, it may be of interest to state briefly some of the results obtained, though no definite conclusion can as yet be drawn. The lawn soils in which this compound was found in considerable amounts seemed to be extremely well suited for the growth of fungi, and it was noted that the rootlets of the trees on this ground were infested with mold. A quantity of oak roots with mold attached was washed free from adhering soil and treated just as the soil had been in obtaining the crystalline material, and there is little or no doubt about the identity of the crystalline materials obtained from the mold and that obtained from the soil. Similar oak roots from another soil and locality not infested with mold did not give the substance. It would seem to be a fair conclusion from this that mold can form dihydroxystearic acid from material associated with tree roots, but what material furnishes the foundation for this formation by fungi, whether it be root excretions or root tissues or cells, it is not possible to say with the information at hand.

This is, of course, not the only way in which dihydroxystearic acid can be conceived of having formed, for it may be produced by the direct oxidation of fats or be formed by biological oxidations from other organic materials, but a discussion of these possibilities would lead far afield from the purposes of the present bulletin.

ROOT EXCRETION AS A POSSIBLE FACTOR IN LAWNS.

To what extent root excretions may affect lawns it is not possible to state definitely, but this much is certain: Plants or soils are affected as the result of the continuous growth of the same plant or by the simultaneous growth of two or more plants. The influence of certain trees or shrubs on the lawn may be, in part at least, ascribed to such a cause. If the excreta of grass itself affects the continuous growth of grass, it is also certain that this effect would show itself more on certain soils than on others, and on a soil suited admirably for the development of grass, such an effect would be entirely eliminated, for the good soil conditions would be able to destroy the unfavorable material from season to season and thus prevent an accumulation, which would take place in the course of time under less favored soil conditions. The association of different grasses and clovers would no doubt aid in prolonging the natural life of a lawn under conditions which would cause the early decadence of a lawn sown to only a single grass. The influence of weeds in this matter of unfavorable effect of one plant on the other is also considerable, apart from their undesirability in lawns because of their appearance, for in a lawn with weeds the grass will disappear gradually and finally give place entirely to the coarser vegetation.

That a plant of the same kind can affect its successors in the same soil can be shown in the following manner: Wheat plants are grown in soil and at the termination of two or three weeks these are cut off and a second crop started in the same soil. At the same time a fresh pot of soil is planted and the two allowed to grow under identical conditions, preferably in a greenhouse. It will be seen that the plants in the soil in which the first crop had grown are materially retarded in growth, as shown by comparison with the growth of the control. This effect is often so great as to cause a growth of only one-half that under normal conditions, but varies according to the nature of the soil or soil conditions under which the experiment is conducted.

A further illustration is found in the so-called sick or fatigued soils, which, after growing the same kind of crop season after season, become unsuited for the further growth of that crop, although other crops may grow profusely.[a] The continued growth of cowpeas in a greenhouse soil caused this to become unfit for further growth of cowpeas. Wheat and potatoes grew well, even luxuriantly. By distillation it was possible to obtain a distillate which was very harmful to cowpeas. The soil from which the distillate was obtained again gave good cowpea growth. From the harmful distillate there was obtained a finely crystallized organic principle which when tested was found to be very harmful to cowpeas. Whether this harmful material was deposited in the soil by the plant and accumulated with the successive croppings under the soil conditions existing, or was due to harmful matter arising in the decay of whatever plant débris might be left in the soil by each crop is left undecided by

[a] Soil Fatigue Caused by Organic Compounds, by Oswald Schreiner and M. X. Sullivan, Jour. Biol. Chem. 6, 39 (1909).

this experiment. The experiment does show, however, that organic substances arising through crop growth, whatever may be their specific origin, can cause soil fatigue or infertility, as illustrated by the present case, although other factors may obtain in other soils or under other conditions.

Another illustration is found in a soil in which sesame had grown in California. Cabbages could not be grown in this soil, while in neighboring rows in the same field on which plants other than sesame had grown previously excellent cabbages were produced. The extract of the soil was likewise harmful to cabbages, but grew excellent wheat plants. This soil when subjected to a laboratory examination yielded organic material, a solution of which in water or in nutrient solutions was found to be harmful to cabbages, but not to wheat.

INFLUENCE OF TREES ON LAWNS.

As far as lawns are concerned this influence is perhaps most noticed in the relationship of trees and grass, a relationship which is only too often the cause of poor lawns under or in the neighborhood of trees. Such bare places under trees are of very frequent occurrence and are usually, and often erroneously, attributed to shade. There can be no question that shade plays an important part in many cases, but usually it is only a contributory factor and the bare places often on closer absorvation are found to be most developed on the side least subject to shade, and on the lower side so far as drainage is concerned. An illustration of this kind is also shown by the fact that two trees of different kinds, growing side by side, with shade conditions as well as all other conditions equal, as far as could be observed, showed an excellent sod of grass up to the very trunk of one of the trees, while under the other scarcely a blade of grass or any other vegetation could be noticed within a radius of about 12 feet. Plate V, figure 1, shows such a condition of bare spot and good lawn under two different trees, the one with the good lawn being a crab-apple tree, the other a pine tree. Effects of this kind are more frequently noticed with maple trees, but other trees are not exempt, and the pines, beeches, lindens, and even oaks are frequently found with sodless surroundings in lawns. The phenomenon seems sometimes to be associated with the general health of the trees themselves, suggesting, as has also been indicated in a previous section, that there may be some relationship between the growth of the trees, fungi, or other tree imperfections and the growth of the grass.

The retention of washings from the leaves and bark of trees is undoubtedly a factor in the infertility of soils in the vicinity of such trees. When water was thrown as a spray upon the trunk of oak, chestnut, and pine trees and the run-off carefully collected and added to a soil extract, this was found to be in each case rendered less suitable for the growth of plants. Similarly, leaves from these trees were washed in water and this water used in the same manner as a culture solution for young wheat plants as indicators with the result that again a harmful influence was clearly apparent.

These illustrations of the influence of one plant on another of the same kind growing in succession in the same soil, or of the influence of one plant on another of an entirely different kind, and the influence of the soil texture, nature of subsoil, and other chemical, physical, and biological factors upon such plant influences or associations will serve to make clear the many antagonisms between grass and weeds, and grass and trees, shrubs, and other plants so often encountered in lawn building and landscape gardening.

Such influences are apt to be observed more generally in soils not well adapted for the purposes for which they are used, owing to faulty texture, bad drainage, poor subsoil conditions, and other defects, so that the nature of the soil becomes really the determining factor.

SOIL BUILDING FOR LAWNS, PARKS, PARKED EMBANKMENTS, AND TERRACES.

In this section it is proposed to discuss some of the principles of soil building applicable to such cases as involve the alteration of soil already in place, the addition of surface soil over soil already in place, and the filling in and leveling of unsightly and unsuited places, for the establishing of private grounds, city parks, and terraces of many kinds; in short, wherever soil is to be transported from one place to another, the object being to establish a greensward on the soil in its new environment. Specific advice or directions applicable to all cases where large civic improvements are contemplated can not be given on account of the necessarily local nature of the problem. General principles can, therefore, only be emphasized, but these are perhaps best illustrated by taking some actual observations made on famous city parks by this bureau as a basis for comments and discussion.

SOIL CONDITIONS IN SOME EXTENSIVE PARKS.

The surface of Central Park, New York, is rolling and presents a variety of soil conditions. The depth of the soil covering varies from a few inches in the vicinity of rock ledges to a depth of several feet in the hollows. This diversity of surface has been judiciously used in planning and executing the landscape improvements in the park.

The value of such a large and useful park in the center of a city like New York can not be overestimated, as it provides a healthful and attractive recreation ground for the residents of the city. The park is justly noted throughout the country for the successful treatment of a difficult problem.

The vegetation, which is one of the chief features of the park, has been quite carefully protected from adverse conditions, such as insect and fungus pests, leaks from gas mains, and other unfavorable influences. The park, however, was beginning to suffer more deterioration in soil conditions as the inevitable result of keeping a single variety of vegetation growing for some time in the same locality, just as in general agriculture soil conditions suffer if a given crop is grown continuously upon the same field.

The areas devoted to grass plats are vigorous in some places, but needing attention in others. The lawns are usually growing upon light soils in which sandy materials predominate. These soils naturally suffer from the summer drought. When grass or shrubs have been planted it has usually been found necessary to give an application of some form of mold. In most cases this dressing has not been repeated in subsequent years. In localities where steep embankments have been made the lawns have suffered from erosion.

Another unfavorable condition, which has probably arisen as a result of maintaining lawns for a considerable period of time, is the advent of various species of grasses such as redtop and orchard and other stooling grasses, together with annual grasses and various weeds.

Proximity of shade trees to the lawns is another factor which is harmful to grass, inasmuch as the water dripping from the branches and flowing from the trunks of the trees often contains tannin and other substances harmful to the growth of vegetation. Furthermore, the shade cast by the trees is a constant factor affecting the growth and kind of grass, especially in the case of trees with dense foliage like the beech. Under the elm trees the grass was better than under any other species of trees observed.

The trees in the park are in most cases well established and have made a very good growth, although considerable effort is required to maintain them in a sufficiently healthy condition. In certain places, however, there are trees which appear to be unthrifty, and in other places young trees have not made the growth which is usual for their kind.

Owing to the adverse conditions of the soils of Central Park, due to the character of the material used in the processes of filling, grading and regrading, the material having been bought of different men by contract at different times and then covered by so-called mold, which most often had none of the characteristics of a mold, but was a dark-brown sandy loam, fine sand, or in some cases a yellow fine sand, no one course of treatment could be prescribed as a panacea for existing ill conditions; and where further surface covering of mold is needed no one kind is suitable to apply in all places.

The artificial top soil constitutes a surface covering which has been applied in order to improve the underlying conditions. Such material, while much like the natural surface soil, is not clayey enough to produce the best results under existing conditions, as it forms a combination of soil too sandy for the production and maintenance of a strong healthy sod.

The character of the underlying material, or subsoil, should be understood in order to make the present soil conditions of the park intelligible. During the processes of regrading and surface soil management which obtained until recent years a great variety of filling material has been used. Often this was of the most nondescript order, constituting rubbish-dump matter, tin cans, broken crockery, pieces of wood, broken stones, street sweepings, broken bricks from fire ruins, coal ashes and cinders, the soil removed when excavating cellars, water-washed sand, and similar materials.

The soils added, furthermore, have usually been applied in layers one above another. Had all the materials been suitable, this would have worked no harm, but in many cases these adjacent bands of soils have been so extremely different in texture and quality as to interfere seriously with the capillary movement of the moisture within the soil and to militate against the most successful growth of plants, shrubs, and trees.

Wherever poor soil materials lie too near the surface it will be necessary to apply further surface covering. Such cover material should be selected with great care and should not only have been productive where it originally occurred, but also of such character as to blend well with the surface material already within the park. Where the addition of material of this nature is necessary this will give the best soil foundation for permanent improvement either by fertilizer or otherwise.

It will be apparent from this that each unit area, say one-fourth acre, should be prescribed for individually. At first thought this may seem expensive, but in reality it may be seen that such a course would effect far greater economy, for instead of a uniform cover which supplies more soil than is needed in some places and less than is needed in others, the same total application or even a smaller one would bring far more efficient results, and the cost of determining the actual needs of each individual area and selecting the kind of material to blend most effectively with the soil already there would be very small as compared with the expensive process of moving greater quantities of mold than might be necessary.

The open areas have generally been left in sod so long that there is some difficulty experienced in keeping them smooth and in retain-ing desirable grasses and eliminating undesirable ones. The first difficulty might be alleviated somewhat at least by rolling the ground when moist, but not soggy. The second difficulty can best be solved, it is believed, by a judicious introduction of some tilled crop for a brief period, such as potatoes or corn, the former being less objectionable, possibly, to the public because less obstructive to the view. Then, when the soil has been well manured with stable manure, for which arrangements have been so well provided in this park, thoroughly subdued and put in good tilth by the processes of cultivation, it will be in good condition for reseeding, with reasonable assurance of reestablishing for a considerable period a lawn of great attractiveness. This same treatment is applicable to areas containing shrubs, plants, and trees whose roots do not come so near the surface as to make cultivation inadvisable.

An examination of poor lawn conditions on another large city park showed that there were considerable areas in which the grass was either suffering severely or had died out on account of insufficient supply of moisture. Borings were made in a great many places in the park, both in good and in poor lawn sections, and the soil was found to be quite variable in texture in the park as a whole, ranging from a mellow loam to a hard compact sandy loam. Below a depth of 12 to 18 inches considerable rubbish in the shape of fragments of stone, brickbats, etc., was encountered; in short, the filling-in was done in a most haphazard and inefficient manner. Spots in which poor structural conditions obtained were found in all the lawn sections on which the grass was nearly or completely parched. The soil in these areas was so bad that it was difficult to penetrate it with an auger, while in the better portions the auger penetrated readily on account of the good mellow structure.

The soil of the nonproductive areas was very dry and had a bleached lifeless appearance. Water from the sprinkler seemed to be unable to enter the soil in such places. The difficulty in this park rests mainly in the unfavorable material, or filling, the lack of organic matter and lack of soil treatment, all of which have contributed to the low water-holding power of the soil and its compactness, preventing the reentrance of water from below when thoroughly dried during a protracted drought. The water-holding capacity of a soil deficient in organic matter is always much lower than in case of a good mellow loam or land that contains enough organic matter to prevent compacting and hardening.

A good grass soil should contain a considerable amount of clay, uniformly mixed with sand and silt, and this should rest upon a clayey foundation. Had this point been held in view when the soil material was hauled in, there would not now be this trouble of poor grass on unsuitable soil.

It is absolutely essential to introduce into these soils some form of organic manure. This can be accomplished by spreading over the soil in the fall well-rotted stable manure which is as free as possible from detrimental weed seeds. This should be fine and well decomposed, so that it will be carried beneath the surface of the grass by rains and snows during the winter, leaving very little material to be raked off in the spring.

Another manure which is now coming to be used more and more for lawn purposes, and especially to be recommended in this case, is the sterilized dry sheep manure, marketed by the stock yards. This manure is obtained in a finely powdered condition and is sown broadcast over the grass. The fineness of the powder permits it to be washed readily into the soil and the result is usually a very striking one. With this sheep manure some finely ground bone meal might also be incorporated, which would still further help in improving the lawn.

Since the soil has been in sod for 12 to 15 years, another good treatment would be to plow the land in the late summer or early fall to a depth of from 6 to 8 inches so as to subject the material to the beneficial action of winter freezes. This would loosen up the compact places, have a tendency to aerate the soil, and allow the moisture to penetrate deeper. Subsoiling, i. e., breaking up the lower strata of soil, might also be practiced with success. Cowpeas or soy beans should be planted the following year and plowed under green when nearly grown. Following this, lime should be applied broadcast to the surface at the rate of from 1,000 to 2,000 pounds per acre. After a good rain the lime should be thoroughly harrowed in and the soil reduced to a good tilth before seeding to grass. The grass should be given a winter top dressing of well-decomposed manure.

In this way there would be secured a tilth favorable to the retention of a supply of moisture sufficient for healthy plant development. Another illustration of soil conditions in a large park is furnished by the famous Boston Common.

This park, one of the oldest, if not the oldest, of large city parks, was found to be suffering from impoverished lawns and trees, and an examination of a large number of soils from different parts of the common was therefore made. In this case also it developed that certain places had been filled in with layers of soil material of various kinds and the mechanical analyses showed the material to vary considerably from place to place, especially in regard to the material serving as subsoil. This was found to occur often in several layers of decidedly different composition and was sometimes of a texture lighter and sandier than the surface soil, too light in fact for a good strong lawn soil. Such filling in as was done had not been done with

FIG. 1.—ADJOINING TREES, WITH GRASS GROWING UNDER ONE AND NOT UNDER THE OTHER.

[Two trees of different kinds, growing side by side, with shade conditions as well as all other conditions equal, as far as can be observed, show an excellent sod of grass up to the very trunk of one of the trees, while under the other scarcely a blade of grass or any other vegetation can be noticed within a radius of about 12 feet.]

FIG. 2.—FAULTY SOIL BUILDING ON PUBLIC GROUNDS.

[The result of not specifying the nature of the soil to be hauled in by the contractors. While the illustration can not show the promiscuousness of the soil as to texture and kind, it does show the bricks and building débris which form no inconsiderable portion of the lawn.]

FIG. 1.—BUILDING DÉBRIS IN LAWN SOIL.

[The presence of bricks, flat tins, boards, and other coarse building débris, found in nearly all small lawns in the cities, is very detrimental to the proper movement of soil fluids.]

FIG. 2.—CARELESS LAYING OF SOD ON IMPROPERLY PREPARED SOIL.

[The débris is almost as great as the actual soil material, and either through ignorance, indifference, or carelessness this débris is covered over with, at best, indifferent sod, with only one possible result, a poor lawn.]

FIG. 3.—BUILDING DÉBRIS FOUND IN A CITY LAWN.

[The débris of buildings and subsoil from the excavations is made to serve as the foundation for the average city lawn. Débris dug up in the attempt to improve a poor spot in the lawn.]

due precautions to the requisites of a good foundation for a permanent lawn.

The following analyses of one of these soils and its subsoil at various depths illustrates this change to sandy material:

Mechanical analyses of heavy soil with light subsoil.

Sample number.	Depth.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
23238	Surface soil, 0-12 inches	2.5	9.3	8.8	20.7	12.9	33.1	12.8
23239	First layer of subsoil, 12-24 inches	1.3	9.6	12.6	30.5	12.2	25.5	8.4
23240	Second layer of subsoil, 24-43 inches	2.5	11.2	17.0	38.5	8.7	14.6	7.6

It will be noted that the clay, silt, and fine sand decrease with depth, whereas the coarser grades increase with depth.

The analysis of another sample in which conditions were natural, rather than made, is as follows:

Mechanical analyses of different strata in natural soil.

Sample No.	Depth.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
23243	Surface soil, 0-12 inches	4.2	11.9	8.7	18.5	13.7	34.5	8.6
23244	Subsoil, 12-20 inches	1.1	4.0	3.6	8.5	10.6	54.0	18.1
23245	Subsoil, 20-27 inches	1.5	4.8	3.8	8.5	12.3	51.6	17.4
23246	Subsoil, 27-43 inches	1.9	3.9	3.4	8.2	19.8	44.6	18.4

Here the clay, silt, and very fine sand increase with depth and the coarser grades decrease, although the surface soil itself is but little lighter than that of the preceding sample, and this soil with heavier subsoil is better suited for park purposes than the sandier soil and subsoil.

The made condition in certain spots in the park is further illustrated by the fact that some of the samples showed an unusually high content of organic matter in the lower layers of soils; for instance, surface soil 4.24 per cent, subsoil 14.95 per cent organic matter, which on closer examination was shown to be due to the presence of coal ashes containing coal fragments and other débris. This high organic matter due to coal ashes was noticed as far down as 6 feet; for instance, surface soil 4.78 per cent, first layer of subsoil 2.09 per cent, deepest layer 7.90 per cent, organic matter.

This improper physical condition is, however, not the only and very likely not the controlling factor in the poor lawn conditions on the common. That it is only a contributing factor is shown by the fact that an organic compound harmful to grass has been found in this soil, together with some other compounds, all of which suggests that the soil is low in oxidative power and very much in need of better aeration.

It was possible to isolate from the soil of this park several definitely crystalline bodies, among them the compound identified as dihydroxystearic acid. This was present in the surface soils examined and it was found very plentiful in the subsoil. It has been found in a number of unproductive lawn soils, as well as in field soils. As already stated, when placed in distilled water or in good nutrient solution this compound shows a marked inhibitive effect upon plant growth, causing a darkening of the roots, thickening of the root tips, and often a turning of the roots into the form of hooks, and is always followed by a checking of the growth of the plant and its ability to feed properly on the nutrients presented to it. As also pointed out, it has been found that the presence of fertilizer salts decreases this harmful effect, and that fertilizers containing nitrates are the most efficient in modifying the harmful action of this compound. The addition of lime and, in fact, any process promoting oxidation is also beneficial. In addition to the presence of this harmful body, several others were found in the soils, namely, a carbohydrate pentosan, and some nitrogenous constituents, hypoxanthine, and cytosine. The presence of these bodies indicates that the aeration in the lawn is poor. A further examination showed that this soil, in common with others containing dihydroxystearic acid, was very low in its oxidative power. A very extensive soil-culture test, using all the possible combinations of fertilizers, was made on a composite of the surface soils and the results obtained with this were in harmony with the conclusion that dihydroxystearic acid and other bodies of this nature were present in the soil, in that the greater response was obtained with the nitrogenous fertilizers. An experiment was also made with all these fertilizer mixtures, together with lime, and it was noted that the lime aided greatly.

The remedial measures suggested by the work, therefore, are to induce in the soil better oxidation, as this has been found to destroy the dihydroxystearic acid and allied compounds. This greater oxidation can be accomplished in a variety of ways: By the addition of nitrogenous fertilizers, especially well-rotted manure; by the incorporation of lime; and by the establishing of better aeration by subdrainage. In any system of improvement contemplated with such soils the application of lime and better oxidation or aeration and perhaps better drainage should form a part. Of course the oxidation is also greatly increased by thorough tillage and growing a cultivated crop for some time.

In some places the sandy nature of the soil, especially the subsoil, seems to make it imperative, in order to insure a good, strong greensward and flourishing trees with diminished tendency to suffer from summer drought, that the soil be improved, especially by making the texture of the subsoil heavier. The added material must not be a stiff, tenacious clay, although at first sight this would seem to be best because the texture of the mixture would seem to be altered most by using it. On the contrary, the soil material which is to be added should be as heavy in texture as possible, but must be selected so that it will blend readily with the soil already in place. Lime, at the rate of 1,000 to 2,000 pounds per acre, should be applied and incorporated with the soil. Coarse bone phosphate may also be added. The surface soil should be treated with manure, lime, and finely pulverized bone phosphate. In this way the faulty texture of the subsoil will be, at least in part, overcome, and the surface soil will be put into condition for the growth of a good greensward.

SOIL CONDITIONS IN CITY LAWNS.

The foregoing illustrations of the conditions brought about in park soils by the use of material utterly unsuited for providing a healthy environment for grasses, with a proper moisture supply in case of drought and good drainage in case of excessive rains, can be added to by the hundreds and thousands when the smaller lawns of city residences are brought into the discussion. And yet it is upon the beauty of shrubs, trees, and grasses on the small city lawn that the general appearance of many cities depends, rather than upon extensive parks, either natural or artificial. The photographs here shown, figures 1, 2, and 3, Plate VI, illustrate how the débris of buildings and subsoil from the excavations is made to serve as the foundation for the average city lawn. The débris in such cases is almost as great as the actual soil material, and either through ignorance, indifference, or carelessness this débris is covered over with at best indifferent sod, and with only one possible result, a poor lawn, which either fails entirely or in part, or through careful and painstaking work on the part of the owner or occupant, enjoys a scanty existence.

In such cases the question is not what is lacking in the soil and what can be added to restore its fertility or what is the proper fertilizer to use. The fact is that nothing is lacking in the soil but soil. In short, there is no soil worthy to be called a soil, for it is lacking in all the essentials to make a proper environment for the growth of any desirable grasses. No amount of fertilizers, manure, or reseeding will make a successful lawn on such ground. There is only one remedy, and that is thoroughly to renovate not the lawn, but the soil. The best way to do this is to dig up the soil for a foot or more and haul it away to make room for a better soil. When this is not feasible, the soil should at least be dug up and screened to remove all building débris and the screened soil considered as a subsoil, limed if necessary, and then a good surface soil from a productive field should be hauled in. This soil should be selected so it will blend in texture with the soil already in place and should be from a productive field recently under cultivation. To it may be added lime, bone phosphate, or stable manure, as discussed elsewhere in the bulletin, in order to improve it further, owing to the inability to improve the soil materially after the lawn is once started.

PROPER AND IMPROPER FILLING-IN OF SUBSOIL MATERIAL.

In the building of the soils of larger city parks where filling-in is often a necessary step, the utmost care in supervision should be exercised in regard to the material used and the method of filling. Had such simple precautions been followed in the past, poor public parks and lawns in public grounds, surrounding public buildings of all kinds, would not now be encountered. The remarks here made apply only to the last 4 feet or so of filling and not to cases where very deep fillings are made.

In the first place, building débris, bricks, and other coarse material should be absolutely barred from these last 4 feet. The soil material which is to serve as subsoil should be preferably of heavier texture than the surface soil available for the lawn, for the reasons already discussed, and never of a distinctly sandy nature, if good results are desired. The heaviest material of the subsoil should be filled in first and as near as practicable distributed over the entire area to be filled in. In large parks each lawn should be considered as a unit. It seems needless to remark that old sidewalks, cement cellars of former buildings, etc., should first be removed, or at least thoroughly broken up, and yet experience has shown that this precaution is seldom complied with. The lighter material of the subsoil is then hauled in on top of the first layer and again spread out in an even layer. Where the material for the fill is all of the same kind and texture, this precaution is unnecessary, but wherever layers are likely to be formed these should be uniformly distributed over the entire area. The heavier layer should be the lowest and all the layers should blend one into the other. Distinctive layering and patches of different cross section in different parts of the lawn should be rigorously avoided. In other words, the usual practice of dumping a load of clayey soil here and a load of sandy soil there, or of dumping a load of clay on top of a distinct sand, can not but fail in bringing about a lack of uniformity in the subsoil of the lawn, resulting in different soil conditions establishing themselves in the course of time, giving patched lawns with poor and good sections or with different grasses growing over the different soil conditions in the subsoil, even if the surface soil be uniform. The importance of the subsoil in the building of lawns can not be overestimated and the greatest care should be exercised where this is built up by filling in. This proper procedure of filling in for lawns costs little if any more than the haphazard way of dumping the material anywhere without due attention to texture and evenness of layering. In making the subsoil, the source of the material is, of course, not so vital a matter as with the surface soil, but it is preferably obtained from grading other places or from the surrounding country, from cuts, embankments, etc., rather than from city street excavations, or building excavations from considerable depths in the heart of a metropolis.

HAULING IN OF PRODUCTIVE SURFACE SOIL.

The surface soil of a lawn must have been a surface soil in its previous situation. It should be especially selected with due regard to the texture of the soil already in place as subsoil and especially in regard to its natural productiveness. The surface soil should blend with the subsoil; that is, its texture should not be markedly different from the subsoil and it should be lighter and loamier than the subsoil for the best results. The surface soil should never be a recently made soil. It is preferably obtained from a cultivated field, as this insures the best soil condition with the least danger of importing weed seeds. Inasmuch as the soil is to be put into permanent sod it is, moreover, better to have had other crops immediately preceding its establishment. It should never be taken from clay or sand banks, cuts, excavations, or similar situations, as no amount of doctoring with fertilizers, manures, or lime will make such soil immediately productive and suitable for a lawn, without previous cultivation and the growing of cultivated crops. Only the very best soil should be obtained for such purposes, and it should further be improved as far as possible by the addition of organic manures, such as stable manure and bone phosphates and in some cases by moderate liming.

The surface soil should be spread over the graded subsoil uniformly. The depth of surface soil to be hauled upon the subsoil depends somewhat upon the nature and texture of the subsoil itself. If the latter is heavy and distinctly of a subsoil character, being hauled in from clay banks or moderately deep excavations, the surface loam should be made quite deep, at least 12 inches, but may in cases where a subsoil is itself good in texture and loamy in character be made much shallower, but seldom less than 6 inches. The object should always be to offer a loamy substratum for the roots to an appreciable depth, so that they can penetrate deeply for their water supply.

SELECTION OF SOIL BEST SUITED FOR GRASS GROWING.

The question of what soil is best suited for the purposes of hauling in as a lawn soil is a very broad one and is naturally a local problem. In the following are given the soil types, which in the States mentioned are prominent grass soils, and may, therefore, be suggestive of the kind of soil to be used in those localities where they occur. For a detailed description of these soil types, together with maps showing their location, the reader is referred to other bulletins from this bureau[a] and the respective reports of the areas in the individual States as far as they have been surveyed.

Prominent soil types suitable for grasses in the States of New York, Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode Island, comprising soils of the glacial and loessial province and the glacial, lake, and river terrace province:

Dover loam and fine sandy loam.
Upshur clay.
Volusia loam and silt loam.
Miami silt loam.
Dutchess silt loam.
Dunkirk clay, clay loam, and fine sandy loam.
Hudson clay loam.
Merrimac loam.
Vergennes clay, black clay, and loam.

Prominent soil types suitable for grasses in the States of Wisconsin, Michigan, Illinois, Indiana, and Ohio, comprising principally soils of the glacial and loessial province and glacial lake and river terrace province, with some soils of the Appalachian Mountains and Plateaus province in eastern Ohio:

Wheeling silt loam and fine sandy loam.
Lintonia loam.
Upshur clay.
Marshall silt loam.
Miami silt loam.
Volusia loam.
Madison loam.
Memphis silt loam.
Portage sandy loam.
Dunkirk clay, clay loam, and fine sandy loam.
Superior sandy loam.

Prominent soil types suitable for grasses in the States of New Jersey and Delaware, comprising soils of the Atlantic Coastal Plain;

Sassafras silt loam, loam, and sandy loam.
Collington sandy loam.

[a] Soils of the United States, by Milton Whitney, Bul. 55, Bureau of Soils, United States Department of Agriculture; Field Operations of the Bureau of Soils, United States Department of Agriculture; Instructions to Field Parties and Descriptions of Soil Types, Bureau of Soils, United States Department of Agriculture.

Prominent soil types suitable for grasses in the State of Pennsylvania, comprising soils of the glacial and loessial province, the Appalachian Mountains and Plateaus province, Piedmont Plateau province, and limestone valleys and uplands province:

Cecil clay.
Chester loam.
Penn loam and silt loam.
Birdsboro silt loam.
Lansdale silt loam.
Dekalb loam and silt loam.
Porters clay.
Hagerstown loam, silt loam, and sandy loam.

Prominent soil types suitable for grasses in the States of Maryland and Virginia, comprising soils of the Atlantic Coastal Plain, Piedmont Plateau, Appalachian Mountains and Plateaus, and limestone valleys and uplands provinces:

Norfolk silt loam and fine sandy loam.
Sassafras loam, silt loam, sandy loam, and fine sandy loam.
Wickham loam and clay loam.
Cecil clay.
Dekalb loam and silt loam.
Holston silt loam.
Upshur silt loam.
Cumberland clay loam.
Hagerstown loam and silt loam.

Prominent soil types suitable for grasses in the States of Kentucky, Tennessee, and West Virginia, comprising principally soils of the limestone valleys and uplands province and Appalachian Mountains and Plateaus province:

Wheeling silt loam.
Lintonia loam.
Tyler silt loam.
Dekalb loam and silt loam.
Holston loam and silt loam.
Porters clay.
Upshur clay.
Decatur clay.
Hagerstown loam and sandy loam.
Cumberland loam.
Brooks clay loam.

Prominent soil types suitable for grasses in the States of North Carolina and South Carolina, comprising soils of the Atlantic Coastal Plain, Piedmont Plateau, and Appalachian Mountains and Plateaus provinces:

Norfolk silt loam and fine sandy loam.
Cecil clay, sandy loam, and clay loam.
Porters clay.
Pilot loam.
Orangeburg fine sandy loam.

Prominent soil types suitable for grasses in the States of Georgia and Alabama, comprising soils of the Atlantic and Gulf Coastal Plains, Piedmont Plateau, Appalachian Mountains and Plateaus, and limestone valleys and uplands provinces:

Houston clay.
Norfolk silt loam and fine sandy loam.
Cecil clay and clay loam.
Hagerstown loam, sandy loam, and clay.
Decatur loam and clay loam.
Orangeburg fine sandy loam.
Greenville loam, sandy loam, and fine sandy loam.
Tifton sandy loam.
Dekalb silt loam.
Upshur loam.
Cumberland fine sandy loam.

Prominent soil types suitable for grasses in the States of Mississippi and Louisiana, comprising soils of the Gulf Coastal Plain province, river flood plains province, and some loessial soils:

Houston clay.
Susquehanna silt loam and fine sandy loam.
Memphis silt loam.
Norfolk fine sandy loam.
Oktibbeha silt loam.
Orangeburg fine sandy loam.
Greenville loam, sandy loam, and fine sandy loam.

SOIL MANAGEMENT IN LAWN MAKING.

The importance of properly preparing the soil for a lawn can not be overestimated. Tillage, plowing, or spading stirs and aerates the soil, improving its physical structure, and accelerating the chemical and biological changes in the soil. The land should be thoroughly cleared of weeds and roots and plowed or spaded as deeply as is consistent with the nature of the soil. It is then harrowed and cross-harrowed with a steel-toothed harrow, or raked; in short, the land is treated just as good farm or garden land should be treated for raising an especially valuable crop. If the soil is very rough after plowing, a disk harrow should first be used to cut up the clods. Where hard-pan exists or where the subsoil is otherwise hard, stiff, or refractory, the subsoil plow should be used. Subsoiling, which consists in stirring up the subsoil without bringing it to the surface, is often of great advantage where the surface soil is thin.

The smoothed soil is then seeded with about 2 bushels of seed to the acre, and this is covered with less than half an inch of soil by harrowing, brushing, or raking. It is advisable to seed again with about the same amount of seed to the acre as before, this time going at right angles to the first sowing and again covering the seed by harrowing. The ground is then rolled with a heavy roller of perhaps 300 pounds.

FIG. 1.—AN ERODED TERRACE.

[In terracing, proper attention must be paid to preventing erosion. Erosion during heavy rainfall is an especial menace to terraces. A soil least subject to erosion should be used in its construction and the surface soil should have a good structure or tilth, well granulated by thorough tillage and liming.]

FIG. 2.—SODDING A TERRACE.

[Laying of sod is perhaps the safest for preventing erosion on newly made terraces. Only good sod grown for such purposes is safe to use, and where such sod is procurable its use in quickly covering terraces is advisable, even though more expensive than seeding.]

FIG. 1.—A GOOD BLUEGRASS LAWN ON SOIL PROPERLY FILLED IN AND PREPARED.

FIG. 2.—AN EXCELLENT MIXED-GRASS LAWN ON THE AGRICULTURAL DEPARTMENT GROUNDS, WASHINGTON, D. C.

This firming of the ground after seeding is one of the most important steps in the process of lawn making, and one which is frequently omitted, especially on smaller lawns. Where the use of a roller is inadvisable, the ground should nevertheless be thoroughly firmed, which can be in a manner accomplished by means of a heavy tamper made by nailing or screwing a heavy board not less than a foot square on the end of a post or other substantial piece of timber.

SOIL IMPROVEMENT WITH FERTILIZERS, MANURES, AND LIME.

Since the soil is to remain in grass for many years, which procedure makes it impossible to add directly to the soil organic manures or commercial fertilizers other than top dressings, it is advisable in all cases to put the soil into the best possible condition, so far as the addition of manures and fertilizers is concerned, at the very start of the lawn making. For this reason copious amounts, 15 to 20 tons to the acre, of stable manure should be used when this is available. The stable manure should be well rotted, so as to have all weed seeds eliminated, but where the stable manure can only be applied in a fresh condition the weed seeds must be allowed to germinate and grow before any grass seed is applied. After destroying the weeds by cultivation the ground is sown to grass. Where well-rotted stable manure can not be obtained, the most advisable procedure is to grow a crop of clover, cowpeas, soy beans, or other leguminous plants and then to plow this under as green manure.

Nearly all soils to be put into grass should be limed with from 1,000 to 2,000 pounds of lime to the acre, which can be added after plowing and then harrowed in. This application of lime must be made several days before sowing the seed. The addition of 300 to 500 pounds of finely ground bone or bone phosphate is also very desirable and may be applied with the stable manure or green manure. At the time of seeding the addition of 200 to 400 pounds to the acre of a high-grade commercial fertilizer will also aid greatly in giving the new lawn a good start.

In advising the use of these manures and fertilizers it must not be inferred that their addition will make a good lawn soil out of a poor raw soil. It is assumed that the soil has already received that attention which is emphasized in the earlier parts of this bulletin, for no amount of such fertilizing or doctoring will make up for a poor soil.

SOIL IMPROVEMENT BY GROWING CULTIVATED CROPS.

The fertilizer improvement above suggested is to be made on what is already a fair soil and one which has been a surface soil for some years. If the soil is texturally good, but in bad physical condition otherwise, or is a raw soil—that is, one which has been a subsoil in its former position—then it is necessary to first change this into a surface soil with good tilth and structure by treating it with manure, fertilizers, and lime and growing a cultivated crop on it for a year or two. A soil which will not grow a good crop of corn or potatoes will not grow a good crop of lawn grass. The cultivation of the ground during the growth of the crop will gradually make a soil out of the raw subsoil and this should be continued until a good potato or corn crop is obtained. A crop of a leguminous plant, like cowpeas, to be plowed under as green manure, as above mentioned, is desirable. Then the soil is ready for its final treatment with lime and fertilizers and seeding to grass. These precautions will insure a good soil for the growth of a permanent greensward and will pay for all the labor expended, especially as without these precautions only an indifferent lawn can be obtained on such soils.

DRAINAGE A FACTOR IN LAWN MAKING.

Attention to proper drainage is a matter which is usually overlooked in laying out lawns, even where these are in large parks or estates. Land that is not naturally able to absorb any ordinary rain, forming pools or water-logged sections, or land that is stiff and heavy with impervious subsoils, or land which is naturally cold, is not well suited for lawn grasses until it has been underdrained. Underdrainage is so generally recognized as a prominent factor in improving unproductive lands for general agricultural purposes that it is surprising that underdrainage has not received more attention in the making of lawns and parks. Drainage has the effect of improving the fertility or productiveness of the lawn soil by carrying off excess of moisture, making it more open in structure, with improved aeration and bacterial activity, and making it warmer, an effect which is especially noticeable in the spring by the early awakening of the grass, which is very gratifying to the observer and moreover tends to establish a much denser turf early in the growing season.

Drainage tiles should be laid 3 to 5 feet deep and from 5 to 20 feet apart, depending upon the nature of the soil. No definite directions can be given in this regard. Much skill is required to dig the trenches accurately and to lay the tile properly. All tile should be laid several months before sowing the grass seed so as to allow the ground to settle completely. The main tiles should be larger than the lateral tiles and a uniform grade be established toward the outlet. This outlet could be easily made in most parks by connecting the drainage system with the sewer pipes and the same can be easily accomplished on the smallest lawn.

Attention has already been called to the effect of tree washing and of tree roots on grass and also of grass on trees. Here, again, the use of tile offers the logical remedy. Tile should be laid on each side of the tree, preferably at the time when it is planted. This will serve to carry off the charged water running from the trees, and cause a better aeration and consequently destruction of débris from the tree. It will make the soil deeper and more productive for both tree and grass, and by causing the tree roots to penetrate deeper into the soil, prevent the interference of the roots of grass and tree. In time the tree roots may get into the tile drains and prevent the free flow of ground waters. The object of laying the tile will have been largely attained before this happens. The tree roots may, however, be removed, as is done in tile drained orchards, by means of a stiff wire brush on a cable.

A further suggestion for removing the washings from the trunks of trees, where this is found to be detrimental to grass, is to have a depression about the trunk or a slight enbankment of sod or even a collar of cement around the base, a foot or two from the trunk, and connecting the basin thus formed with the underdrainage system by means of an upright tile.

In digging the trenches for the laying of tile, the soil and subsoil should be kept separate so that the surface soil can again be put on the top when the trench is filled.

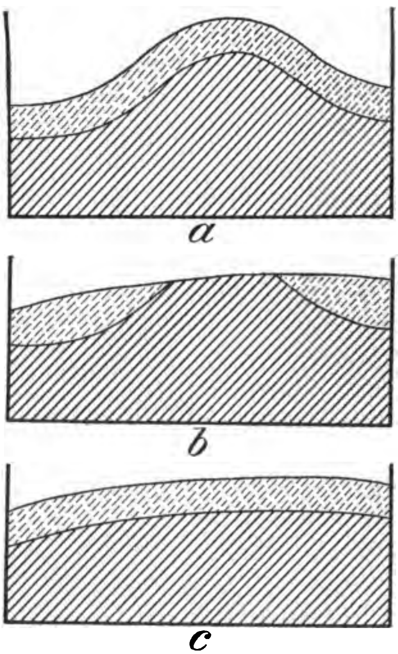


FIG. 3.—Proper and improper soil grading. *a*, soil to be graded; *b*, improper grading, showing exposure of subsoil; *c*, proper grading.

IN GRADING, SUBSOIL MUST NOT BE EXPOSED.

All grading in the establishing of lawns should be done while the land is in the rough just after the first breaking of the soil by plowing. When the surface soil is deep and the grading slight, no special care is required, but where the soil is shallow and the regrading to be done considerable, care must be exercised so as not to expose the subsoil in certain sections or make the surface soil so shallow as to prevent the proper growth of grass. Where the regrading is considerable the proper procedure is to take up the surface soil and put it aside; then do all the necessary grading on the subsoil thus exposed. After grading, the surface soil is again uniformly spread over the land. This is a more economical procedure than to haul in fresh surface soil in after years to renovate the impoverished sections of the lawn where the subsoil was exposed and furthermore avoids the difficulty often found in procuring surface soil. In figure 3 is shown the right and wrong way of soil grading.

IN TERRACING, PROPER ATTENTION MUST BE PAID TO PREVENTING EROSION.

In making terraces on lawns, as in grading, the exposure of subsoil must be avoided either on the slope or the top of the terrace. Erosion during heavy rainfall is an especial menace to terraces. For this reason a soil least subject to erosion should be used in their construction, especially in those cases where the terraces are artificially formed by the hauling in of soil. The surface soil should be one having a good structure and tilth, as a soil well granulated by thorough previous tillage, cultivation, and liming is less liable to erosion. Soils which puddle readily—that is, readily lose their structure on the addition of water—are also the ones which erode most readily when on terraces. The surface soil should blend well with the subsoil and the latter should be one which will admit of rapid drainage with no tendency to form hard or dry layers impeding the downward movement of water. In stiff subsoils these drainage factors can be greatly helped by tile drainage as on level land, thus insuring the percolation of water through soil and subsoil rather than over the surface of the terrace slope.

The grasses used on terraces should also be selected with a view to obtaining the greatest retention of soil. The grasses having a binding tendency by virtue of their extensive root growth and spreading tops are especially applicable. Rhode Island bent is especially valuable on terraces. Mixtures of this with Canada and Kentucky bluegrass may be made where these are used in the rest of the lawn. Canada bluegrass can be used in many sections with good results as a soil-binding grass on cuts and fills. The aggressiveness of the grass and its tough sod make it of great value in preventing erosion. Beach grass is a valuable soil binder for dry, loose, sandy soils on cuts and embankments. Bermuda grass can also be used for binding banks and is useful on dry slopes of lawns.

The laying of sod is perhaps the best procedure for preventing erosion on newly made terraces, but carries with it all the difficulties of sodding, greater expense, introduction of weeds and undesirable grasses, and other undesirable features. Only good sod grown for such purposes is safe to use, and where such sod is procurable its use in quickly covering terraces is advisable, even though more expensive than seeding. This additional expense is perhaps no greater than that incurred by repairing a partially eroded terrace a second or even a third time. The laying of sod does not mean, however, that the condition of the soil on the terrace slope can be neglected because so quickly rendered invisible.

MAINTAINING GOOD SOIL CONDITIONS IN LAWNS.

Fertilization will never make up for a lawn soil poorly prepared. It is difficult to make good soil conditions after a lawn is started when the poor conditions are due to one or all of the soil factors already discussed as causing defective lawns. No amount of fertilization will remedy these. If the lawn soil has been properly prepared in the first place and enriched with stable manure, lime and bone phosphate, there ought to be no need for fertilizer application for 10 or 12 years other than the usual fall or winter mulch of stable manure or other organic covering.

MULCHING WITH MANURES IN FALL OR WINTER.

The stable manure must be well rotted, otherwise it will do more harm than good through the introduction of weed seeds. Fresh manure is sure to introduce weed seeds. Other coverings are muck and peat, compost, and tobacco stems, all of which make a good mulch. The benefits to the soil are that the mulch minimizes the damage from alternate freezing and thawing, and that it supplies, through the leaching of winter rains and snows, dissolved inorganic and organic constituents, which sink into the soil and thus promote the good conditions necessary for grass growth. The manure is allowed to stay on the ground all winter and is left until the grass has begun to grow vigorously in the spring, when the coarse material is removed. The lawn should then be thoroughly rolled with a heavy roller, or on an extremely small lawn firmed with a tamper, as already described.

IMPORTANCE OF ROLLING THE LAND IN THE SPRING.

Rolling is very essential, as the alternate freezing and thawing has raised the individual root clusters above the general level of the soil surface. Buried stones, bowlders, and bones are frequently brought to the surface through the same action of freezing and thawing in the course of years. If these raised root clusters are not rolled down while the ground is soft, they will become so prominent as to destroy the evenness of the lawn, and in the course of years cause a broken appearance similar to the boggy effect noticed in old pastures. Rolling in the early spring will do much to secure a uniformly even greensward.

APPLICATION OF FERTILIZERS.

The means for maintaining the fertility of agricultural lands are thorough tillage, crop rotation, and fertilization. Tillage and crop rotation are excluded after the lawn is once established and fertilization must take the form of superficial application, inasmuch as it is